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Development of a Scoring Algorithm for Flight Crew Intervention Credit in System Safety Assessments

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16. Abstract

According to current regulations for type certification of large commercial aircraft, certification credit may be taken for correct and appropriate action for both quantitative and qualitative assessments provided that some general criteria are fulfilled. According to the same regulations, quantitative assessments of the probabilities of flight crew errors are not considered feasible. As a consequence, the system designer is allowed to take 100% credit for correct flight crew action in response to a failure. Earlier research has indicated that this leads to an overestimation of flight crew performance.

The overall goal of this research effort was the development of a method that would allow certification credit for good human factors design practice in certification regulation. This method consists of a scoring algorithm that combines key flight deck design characteristics into an overall level of certification credit for flight crew intervention in the case of system failures.

The method is easy to apply, provided that the system failure modes are associated flight deck annunciations are known. As expected, application of the method to a number of example cases shows that it differentiates between system failures and between aircraft types. The method also produces higher average scores for more modern cockpits.

Although every possible effort was spent in making this a valid, practicable, and acceptable method, it is still the result of a research project. Further development is recommended.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
ADF	Automatic direction finder
ADI	Attitude director indicator
ADIRU	Air Data Inertial Reference Unit
ADR	Air Data Reference
AFM	Aircraft Flight Manual
AOM	Aircraft Operations Manual
ARAC	Aviation Rulemaking Advisory Committee
ATC	Air traffic control
ATS	Autothrottle system
ATT	Attitude
APU	Auxiliary power unit
CAA	Civil Aviation Authority
CAP	Central annunciator panel
CB	Circuit breaker
CDU	Control display unit
CFR	Code of Federal Regulations
c.g.	Center of gravity
DC	Direct current
DU	Display unit
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitor
EGT	Exhaust gas temperature
EFIS	Electronic Flight Instrument Systems
EHAM	Amsterdam Airport Schiphol
EICAS	Engine Indication and Crew Alerting System
EIS	Engine Instrument System
EPR	Engine pressure ratio
FAA	Federal Aviation Administration
FL	Flight level
FMC	Flight Management Computer
FMS	Flight Management System
GPWS	Ground Proximity Warning System
HDG	Heading
HP	High pressure
IAS	Indicated airspeed
IMC	Instrument Meteorological Conditions
IRS	Inertial Reference System
L/G	Landing gear
LGCIU	Landing gear control and interface unit
LH	Left hand
MFD	Multifunction display
MFDS	Multifunction display system
MFDU	Multifunction display unit

ND	Navigation display
NPA	Notice of Proposed Amendment
PF	Pilot flying
PFD	Primary flight display
PNF	Pilot not flying
psi	Pounds per square inch
QNH	Queens Nautical Height (Altimeter setting to obtain height above mean sea level)
QRH	Quick Reference Handbook
RH	Right hand
RMI	Radio magnetic indicator
TAS	True airspeed
TGT	Turbine gas temperature
TO	Takeoff
TRU	Transformer rectifier unit
VHF	Very high frequency
VMC	Visual meteorological conditions
VOR	VHF Omnidirectional Range
VSI	Vertical speed indicator

EXECUTIVE SUMMARY

The aircraft type certification regulations include the requirement to conduct a system safety assessment to demonstrate compliance with these regulations. One way to mitigate the effect of a system failure is appropriate corrective action by the flight crew. According to current regulations for type certification of large commercial aircraft, certification credit may be taken for correct and appropriate corrective action for both quantitative and qualitative assessments provided that some general criteria are fulfilled. According to the same regulations, quantitative assessments of the probabilities of flight crew errors are not considered feasible. As a consequence, the system designer is allowed to take 100% credit for correct flight crew action in response to a failure. Earlier research has indicated that this leads to an overestimation of flight crew performance.

The overall goal of this research effort was the development of a methodology that would allow certification credit for good human factors design practice in certification regulation. The research consisted of five phases, with this report presenting the results of phase 5. In the previous phases of the project, a list of key flight deck design characteristics with descriptors for different performance levels was developed. The objective of phase 5 was twofold. The first objective was to develop a scoring algorithm that combines the design characteristics into an overall level of certification credit for flight crew intervention in the case of system failures. The second objective was to validate the method by applying it to a number of cases and comparing the results with a set of predefined success criteria.

Validation and verification of the method was done in three ways: (1) The method was applied to 68 cases of in-flight aircraft system failures. The cases describe failures of four different systems for eight different aircraft types; (2) All failure cases for the Fokker 100 aircraft were replayed in a Fokker 100 level D training flight simulator; and (3) A form of validation was provided by discussing the design of the Fokker 100 cockpit with representatives of the original Fokker design team. The latter activity will be referred to as the matrix sessions. The objective of the simulator experiment and the matrix sessions was to verify if the method captured all relevant aspects of flight deck design in the context of failure handling.

The method is easy to apply, provided that the system failure modes and associated flight deck annunciations are known. The time needed to determine the amount of flight crew intervention credit for a single aircraft and failure case combination depends on the complexity of the system and the associated failure, and the familiarity of the analyst with the system involved. In the analyses, where the analysts had only limited pre-existing knowledge of the aircraft systems, application of the method required approximately 1 to 2 hours per failure case. Application of the method was expected to take only 10-15 minutes per failure case provided the analysts were familiar with the systems involved, as expected during application of the method as part of the aircraft’s type certification process.

The simulator experiment and the matrix sessions confirmed the importance of the key characteristics that are the backbone of the scoring method. The simulator experiment and the matrix sessions did not reveal any omissions on that list of characteristics.

As expected, application of the method to a number of example cases shows that it differentiated between system failures and between aircraft types. The method produces higher average scores for more modern cockpits. The most modern aircraft in the example cases (Boeing 777 and Airbus A330) did not obtain the maximum possible score, indicating that even for those aircraft, there is room for improvement.

As results of phase 1 of this study have shown, a method for determining realistic levels of flight crew intervention credit in system safety assessments could result in significant flight safety improvements. Although every possible effort was spent in making this a valid, practicable, and acceptable method, it is still the result of a research project. Therefore, it is recommended for consideration that the Aviation Rulemaking Advisory Committee (ARAC) be informed of the results of this study so that, under the guidance of ARAC, this method can be further developed.

1. INTRODUCTION.

1.1 BACKGROUND.

Current certification requirements for system design and analysis were initially developed around 1970 when long-range, wide-body aircraft such as the Boeing 747, the Douglas DC-10, and the Lockheed L-1011 appeared. These requirements are based on the principle stating that an inverse relation should exist between the probability of malfunctions and the degree of hazard to the aircraft and its occupants. A detailed failure modes and effects analysis and fault tree analysis are often necessary to demonstrate compliance with these regulations [Title 14 Code of Federal Regulations (CFR) Part 25.1309 and Advisory Circular (AC) 25.1309-1A].

One way to mitigate the effect of a system failure is by appropriate corrective action by the flight crew. The current advisory material AC 25.1309-1A states:

> "When assessing the ability of the flight crew to cope with a failure condition, the warning information and the complexity of the required action should be considered (reference Paragraph 8g(5)). If the evaluation indicates that a potential failure condition can be alleviated or overcome during the time available without jeopardizing other safety-related flight crew tasks and without requiring exceptional pilot skill or strength, credit may be taken for correct and appropriate corrective action, for both qualitative and quantitative assessments."

The AC also states that quantitative assessments of the probabilities of flight crew errors are not considered feasible. As a consequence, probabilities of either 0 or 1 are put in the fault trees. Accordingly, the system designer is allowed to take 100% credit for correct flight crew action in response to a failure.

Since the development of certification regulations around 1970, research was conducted in the human factors field, resulting in a better understanding of the effectiveness of various design features for human-machine interfaces. This is reflected in the design of current-generation flight deck crew interfaces and aircraft certification regulations, like European Aviation Safety Agency (EASA) Notices of Proposed Amendment (NPA) 15/2004, which proposes to add a new paragraph, CS 25.1302 Human Factors, to the existing Airworthiness Code. However, good design practice, which would be expected to enhance the reliability, timeliness, or effectiveness of flight crew intervention, is not rewarded in the quantitative analyses used to show compliance with 14 CFR Part 25.1309. Current regulations and associated guidance material do not provide criteria that encourage or require manufacturers to develop and follow a flight deck design process that comprehensively addresses human performance considerations. To provide such an incentive, a methodology is needed that would provide certification credit for desirable design features.

The Federal Aviation Administration (FAA), in cooperation with Civil Aviation Authority (CAA) - The Netherlands, agreed to initiate research on the development of a methodology that would allow appropriate levels of certification credit for good human factors design practice inflight decks, for those situations in which flight crews are expected to take actions to mitigate system failure conditions. This methodology should establish a rational scheme for evaluating designs based on easy-to-understand characteristics, eventually resulting in a number that is permissible in the system safety assessment. The methodology should provide several levels of credit to differentiate significantly different designs and should give full credit to what is considered to be best design practice.

This methodology is expected to have several potential effects. Using current guidance material, the system designer can take 100% credit for correct flight crew action in many or most failure conditions. The proposed methodology would provide the possibility for that same 100% credit, but only in cases where the design adequately supports effective performance. As a result, some designs may get less than the full credit they now receive for correct flight crew action, which may in some cases, result in the design failing to meet the integrity or availability requirements of 14 CFR 25.1309. In such cases, the system designer would have several possible ways to improve the design:

- Improve the flight crew interface by changing the alerting, the complexity of the procedure, or the actions that the flight crew is expected to take.

- Make the system less dependent on flight crew intervention by reducing the likelihood of the failure or in some way mitigating the consequences of the failure.

The methodology should be complementary to planned rule-making for 14 CFR 25.1322, Warnings, Cautions and Advisories, which is being expanded to cover modern alerting systems.

The overall research project for the development of a method to establish flight crew intervention credit was conducted in five phases:

- Phase 1 Investigation to assess the safety leverage of the proposal
- Phase 2 Investigation into alternative solutions for the problem
- Phase 3 Development of the methodology
- Phase 4 Reality check
- Phase 5 Validation

The underlying report describes the result of phase 5, Validation.

1.2 OBJECTIVE.

The goal of this research effort was the development of a methodology that would allow credit for good human factors design practice in aircraft certification regulation for those situations in which flight crews are expected to take actions to mitigate system failure conditions. A list of key design characteristics with descriptors for different performance levels was developed in previous phases of the project [Roelen and Wever 2002, Roelen and Wever 2004, and Roelen, et al., 2005]. The objective of this phase was twofold. The first objective was to develop a scoring algorithm that combined the design characteristics into an overall level of certification credit. The second objective was to validate the method by applying it to a number of system failure cases, evaluating the outcome and comparing the result with a set of predefined success criteria.

2. SCORING ALGORITHM.

2.1 GENERAL CONSIDERATIONS.

A list of key design characteristics that influence flight crew intervention in case of system failures was developed in previous phases of the research [Roelen and Wever, 2004, and Roelen, et al., 2005]. The basic steps in the human response process—detection, decision, and action—serve as a framework for the list of design characteristics, see figure 1. The figure shows the three basic steps and associated high-level characteristics. A failure to properly conduct any of these steps is considered to be an inappropriate response. For each step in the response process, influencing factors were related to characteristics of the design. Selection of key design characteristics was based on a detailed review of accidents and incidents involving inappropriate flight crew response to system failures, combined with academic knowledge from human factors literature. The resulting list of 14 key design characteristics is presented as a series of multiple choice questions, see appendix A. The list of design characteristics is summarized in table 1.

Detection	Decision	Action	
		Single action	Procedure
• Timely	• Awareness of current status	• Observe	• Skill
• Rousing	• Nature and location of the failure	• Reach	• Workload
• Unambiguous	• Required corrective action	• Operate	• Feedback
• Obvious	• Awareness of required status		• Not jeopardizing other tasks
	• Integration and prioritization		

Figure 1. Steps in the Flight Crew Intervention Process

Because the method is intended to be applicable to a wide range of possible designs and systems failures, the design characteristics are described in a generic way. In the accompanying text, examples are used to illustrate how each design characteristic should be interpreted.

Table 1. Summary of Key Design Characteristics

No.	Characteristic
1	Explicit annunciation
2	Inherent cues
3	Prioritization
4	Removal of misleading information
5	Unambiguous system condition messages
6	Presentation of the procedure

Table 1. Summary of Key Design Characteristics (Continued)

No.	Characteristic
7	Deactivation of attention getter
8	Hand guidance
9	Feedback after inappropriate action
10	Conditional expressions in the procedure
11	Interference with other tasks
12	Feedback after procedure
13	Prompting of deferred actions
14	Feedback after action

This method is not intended to provide a final judgement on a particular design, but rather to serve as a starting point for the discussion between the applicant and the certification authorities. Therefore, every effort was made to make the method as complete, objective, and unambiguous as possible, enabling design organizations to use the method even before the formal start of certification activities.

The following system design information is required to be able to properly complete the list of key design characteristics:

- A description of the user interface (e.g., engineering drawing).

- A description of the location of the user interface in the cockpit (e.g., engineering drawing).

- A complete description of the failure manifestation for the particular system failure for which flight crew intervention credit is sought. This description should include designed characteristics (annunciation light, instrument reading changes, messages on Engine Indicating and Crew Alerting System (EICAS) and Electronic Centralized Aircraft Monitor (ECAM) or similar displays, etc.) as well as inherent characteristics (vibration, smoke, etc.).

- The proposed failure recovery procedure for the particular system failure.

- Because the current maximum level of credit is 1, it would be very difficult to justify a lower level of flight crew intervention credit for newer designs. In fact, this could be counterproductive as it would provide an obstacle for introducing newer and safer systems into aircraft.

- A maximum value lower than 1 would always have to be selected arbitrarily.

This method only considers system failures in the context of a System Safety Assessment. System failures or system failure effects that were not foreseen in the design and development process of the system are, by definition, out of the scope of this method. However, experience has shown that unforeseen system failures do occur. It is considered good design practice to account for the fact that the flight crew will take corrective action in response to unforeseen failures. In developing the method, it was assumed that the overall SSA in which this method would be applied was of sufficient quality and completeness. It was assumed that the SSA would consider that flight crew intervention after a system failure can also occur in cases where certification credit is not sought.

The Fokker 100 accident on October 31, 1996, near São Paulo, Brazil, provides such an example. The aircraft was performing a regular passenger flight from São Paulo to Rio de Janeiro. The flight crew had been unable to arm the autothrottle during taxi-out, but was unaware that this was the result of an unlocked thrust reverser at the right-hand (RH) engine. During takeoff, immediately after leaving the ground, a series of uncommanded thrust reverser deployments of the RH engine started. On this aircraft type, a thrust reverser deployment is accompanied by a retardation of the associated thrust lever. The flight crew interpreted this as a failure of the autothrottle, which they tried to overcome by manually advancing the throttle levers. During this attempt, the safety cable that connects the throttle with the thrust reverser snapped. This resulted in a situation where the RH engine provided maximum thrust, but with a deployed thrust reverser. During the next 24 seconds of flight, the aircraft drifted towards the right, reaching an attitude of pronounced tilting to the right and eventually collided with the ground. All 89 passengers and 6 crewmembers died in the accident, in addition to 4 people on the ground.[1] In the Fokker 100 aircraft, the 'reverser unlocked' warning is inhibited during takeoff. The objective of inhibition is that during critical flight phases, such as takeoff, the flight crew is expected to fly the aircraft and not be distracted by warnings or cautions. In this case, clearly, certification credit was not sought by the manufacturer, yet the flight crew intervened to solve the problem.

It is assumed that the system under evaluation is in compliance with existing regulations, such as 14 CFR Parts 25.1309 and 25.1322. The objective of the applicant may not necessarily be to obtain the maximum score. This method is intended to determine how much flight crew intervention credit may be claimed. Applicants may have good reasons not to claim maximum credit for particular system failures, e.g., for those failures with low criticality levels.

The applicant can use the method during the system development process to identify elements for design improvement (e.g., human factors) and as a way to structure the communication and discussion between design teams of different systems. This can contribute to human factors improvement and for individual designs for the cockpit as a whole.

Before applying the method to determine the credit level, the applicant should establish all necessary failure recovery and mitigation steps. It must be recognized that failure recovery and mitigation may not stop after the immediate problem has been solved. In case of a fuel leak, for instance, isolation of the leaky fuel tank solves the immediate problem, but a safe landing requires additional steps, such as recalculating the aircraft's range and planning for an alternative destination.

[1] Ministerio da Aeronautica, Estado-Maior da Aeronautica (Brazil), Aeronautical Accident Investigation and Prevention System, Cinepa 04, Final Report, Aircraft Model Fokker 100, Congonhas Airport, Sao Paulo, 31 October 1996.

2.2 THE ALGORITHM.

Expert judgement was used to rate each of the design characteristics. Two expert panels were consulted, one in Amsterdam and one in Seattle, WA. The expert panel in Amsterdam consisted of seven people. Four experts were active pilots, while the other three had experience in aircraft system design and certification. The expert panel in Seattle consisted of 13 people, all from the FAA. Ten experts were system engineers with various specialties, two were human factors specialists, one of whom was also an experiment pilot. Experts were asked to rate the possible performance levels of each characteristic as full, partial, or zero. Full meant that if a certain characteristic met the description, it should receive full credit. Partial meant that if a certain characteristic met the description, it should receive only half of the full credit. Zero meant that if a certain characteristic met the description, it should receive no credit at all. The results are presented in table 2.

Table 2. Credit Levels for Each of the 14 Design Characteristics

Characteristic	Credit
1 Annunciation	
Yes, alert provided	Full
No alert	No
2 Inherent cues	
Yes, inherent cues present	No
No inherent cues	Full
3 Prioritization	
Yes, priorities established	Full
No prioritization	No
4 Removal misleading data	
No misleading data	Full
Misleading data removed	Full
Misleading data not removed	No
5 Unambiguous	
Yes, unambiguous data	Full
No, ambiguous data	No
6 Procedure presentation	
Procedure presented	Full
Procedure prompted	Partial
Procedure not presented	No
7 Alert deactivation	
Manual deactivation	Full
Automatic deactivation	No
Deactivation after completion	Partial
Not applicable	No

Characteristic	Credit
8 Sequential guidance	
Yes, guidance provided	Full
No guidance	No
Not applicable	Full
9 Feedback on action	
Yes, feedback provided	Full
No feedback	No
10 If-then statements	
Yes, procedure contains if-then	No
No if-then	Full
11 Task interference	
Yes, task interference	No
No task interference	Full
12 Feedback task completion	
Yes feedback after completion	Full
No feedback	No
13 Deferred actions	
Deferred action prompted	Full
Deferred action not prompted	No
Not applicable	Full
14 Feedback on input	
Yes, feedback on control input	Full
No feedback on control input	No
Not applicable	Full

The overall credit level is obtained by summation of the amount of credit obtained for each of the 14 characteristics. The total result is normalized to obtain a value between 0 (minimum credit level) and 1 (maximum credit level):

$$S = 1/14 \sum_{i=1...14} C_i \qquad (1)$$

where:

S = Overall credit level
C_i = Credit level for characteristic i

C_i can be 1 (full credit), 0.5 (partial credit), or 0 (no credit).

3. VALIDATION.

3.1 INTRODUCTION.

Validation and verification of the method was performed in three ways. First, the method was applied to 68 cases of in-flight aircraft system failures. The cases describe failures of four different systems for eight different aircraft, according to the scheme in table 3.

Table 3. Overview of Aircraft Type and System Combinations Selected for the Validation Process

System and Aircraft Type	Avionics and Instruments	Electrical	Landing Gear and Hydraulic	Powerplant
Airbus A330	2	2	2	2
Boeing 777	2	2	2	2
Airbus A310	2	2	2	2
Boeing 737-500	2	2	2	2
Fokker 100	3	3	3	3
Fokker 28	2	2	2	2
Fokker 50	2	2	2	2
Fokker 27	2	2	2*	2

*For the Fokker 27, a failure of the pneumatic system was selected.

Second, all failure cases for the Fokker 100 were replayed in a Fokker 100-level D training flight simulator. Four Fokker 100 simulator sessions were conducted. The crews of each session included one pilot without a Fokker 100 type rating but with a type rating for another large transport aircraft type, and one pilot with a Fokker 100 type rating. The pilots with the Fokker 100 type rating were part of the research team. The objective of having a pilot without experience on the type was to be able to observe more closely how the cockpit supports the flight crew in mitigation of system failures.

Third, a form of validation was performed via discussion of the design of the Fokker 100 cockpit with representatives of the original Fokker 100 design team. The discussion focused on expected flight crew behavior in the case of a system failure, with the aim to capture argumentation for the flight deck design and flight warning computer design. Participants of this discussion included three key players in the Fokker 100 flight deck development process (i.e., experiment pilot, chief experiment pilot, and cockpit design engineer).

3.2 SUCCESS CRITERIA.

The following criteria were applied to determine if the method was valid:

- The method should be straightforward to apply, without requiring extensive knowledge of human factors.

- The method should be unambiguous, producing similar results if applied by different people.

- Application of the method should not be excessively time-consuming.

- The method should be distinguishing, such that good human factors design practice is rewarded.

- The method should be complete, covering all relevant flight deck characteristics.

3.3 APPLICATION OF THE METHOD.

To meet the objectives of this part of the study, aircraft from different generations and different manufacturers were selected. A precondition for this selection was the availability of information to conduct the safety assessment and to apply the methodology. Available time and budget were other limiting factors for this task. The aircraft types selected for this study are listed in table 4.

Table 4. Aircraft Types Selected for the Analysis

Aircraft Type	Generation	Propulsion Type
Airbus A330	4th	Jet
Boeing 777	4th	Jet
Airbus A310	3rd	Jet
Boeing 737-500	3rd	Jet
Fokker 100	3rd	Jet
Fokker 50	3rd	Turboprop
Fokker 28	2nd	Jet
Fokker 27	1st	Turboprop

The selection of the systems used in the evaluation was based on the results of the phase 1 study. In Roelen and Wever 2002, the appropriateness of crew response to system failures was compared across aircraft systems. Based on those results, it was decided to include avionics and instruments, the electrical system, landing gear and hydraulics, and the powerplant in the analysis. Two failure cases per system, per aircraft type, were evaluated with the methodology. Similar failures were evaluated for the different types of aircraft to allow for a proper comparison of results across aircraft types and across aircraft generations. For example, an engine seizure was evaluated for all types of aircraft. Three failure cases for each system were selected for the Fokker 100, as this aircraft provided the baseline for which detailed design knowledge and documentation was available; and the Fokker 100 was the subject aircraft in the simulator experiment.

The assessment was conducted by the authors. Aircraft Flight Manuals, as well as Aircraft Operations Manuals, were used as primary sources of information. A complete list of sources is provided in section 5 of this report. In the case of annunciated failures, a 100% effectiveness of the annunciator was assumed. A detailed description of each aircraft and system failure combination is provided in appendix B, and a summary of results is presented in figures 2 to 11.

3.3.1 Comparison of Credit Levels.

The results of the analysis of the selected failure cases were used directly to calculate credit levels for aircraft and system failure combinations, using equation 1 and table 2. These results are summarized in appendix B, section B.9 and presented in figures 2 to 9. In addition to the credit level for each individual aircraft type and system failure combination, the average credit level for each aircraft was calculated, as presented in figures 10 and 11. The aircraft types in figure 10 are rank-ordered according to the date of their first flight, with the oldest aircraft (F-27) on the left and the newest (Boeing 777) on the right. Figure 11 presents the same results, but the aircraft are grouped by aircraft manufacturer, and for the Fokker aircraft, a distinction is made between jet and turboprop aircraft.

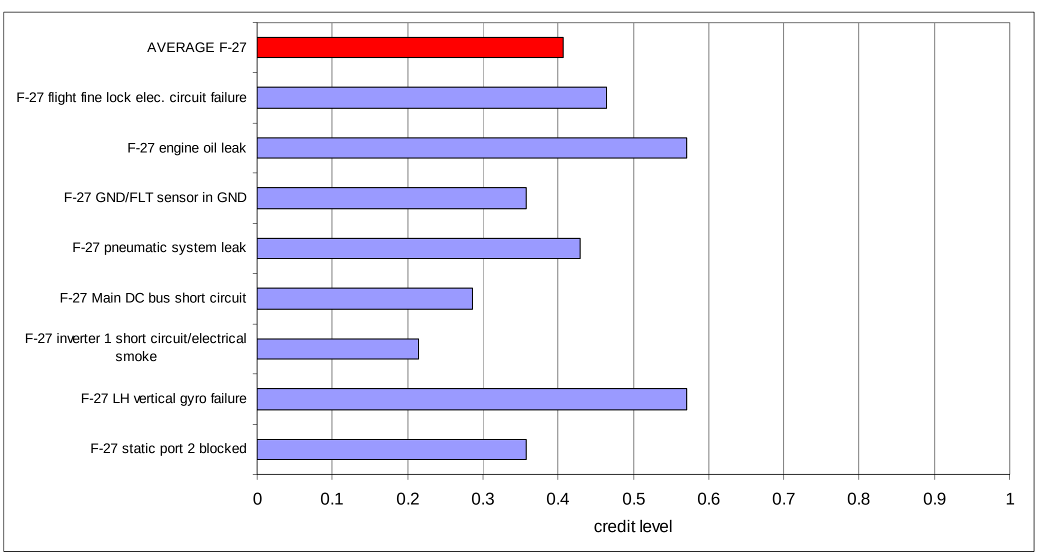

Figure 2. Fokker F-27 Mk500 Results

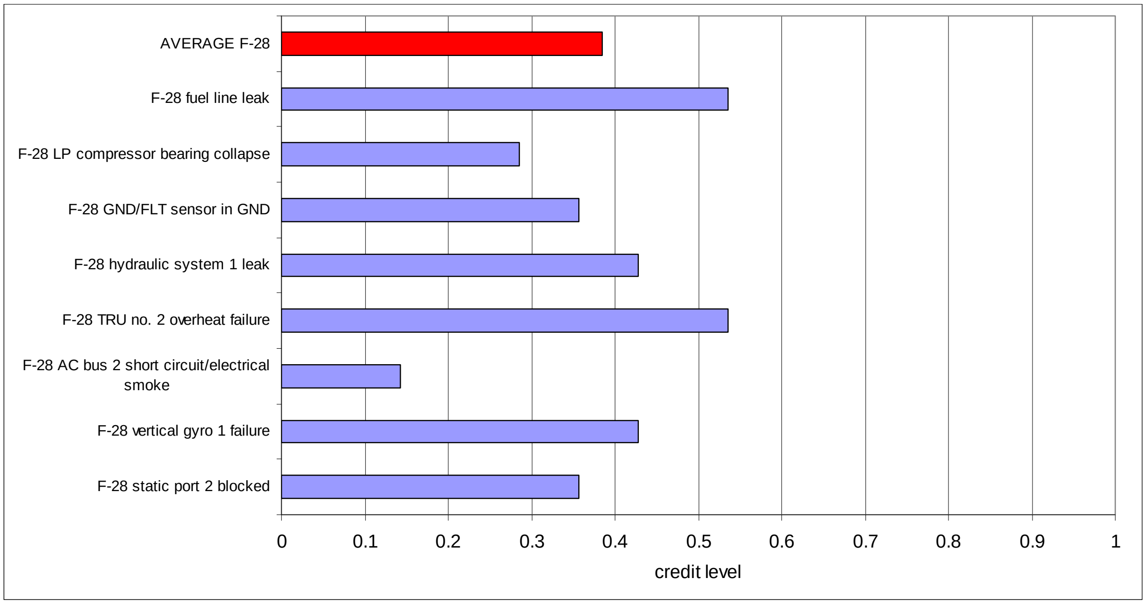

Figure 3. Fokker F-28 Results

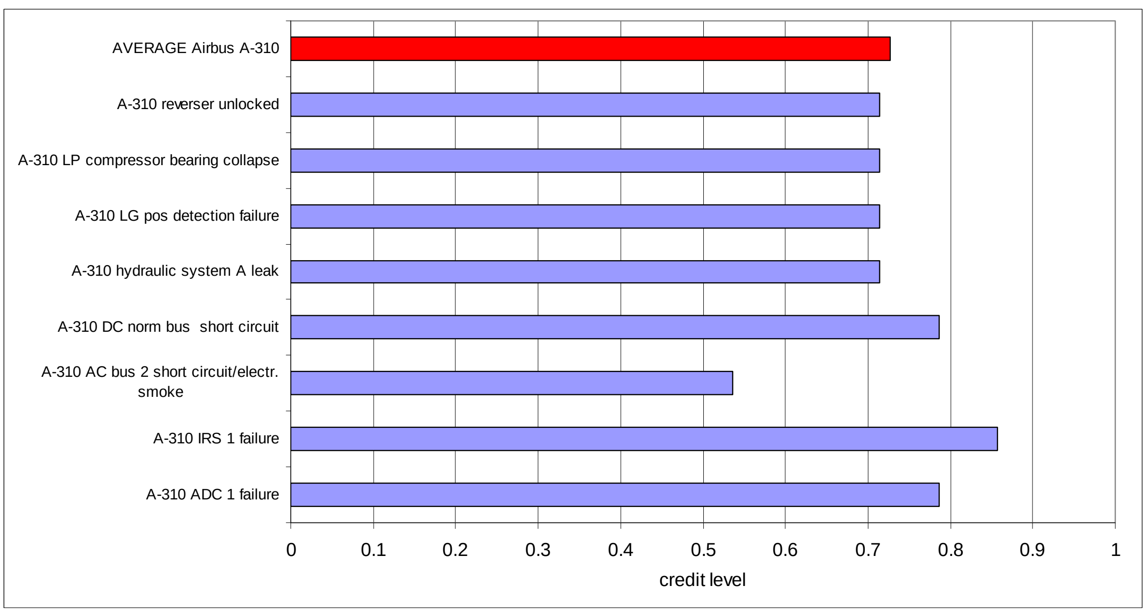

Figure 4. Airbus A310 Results

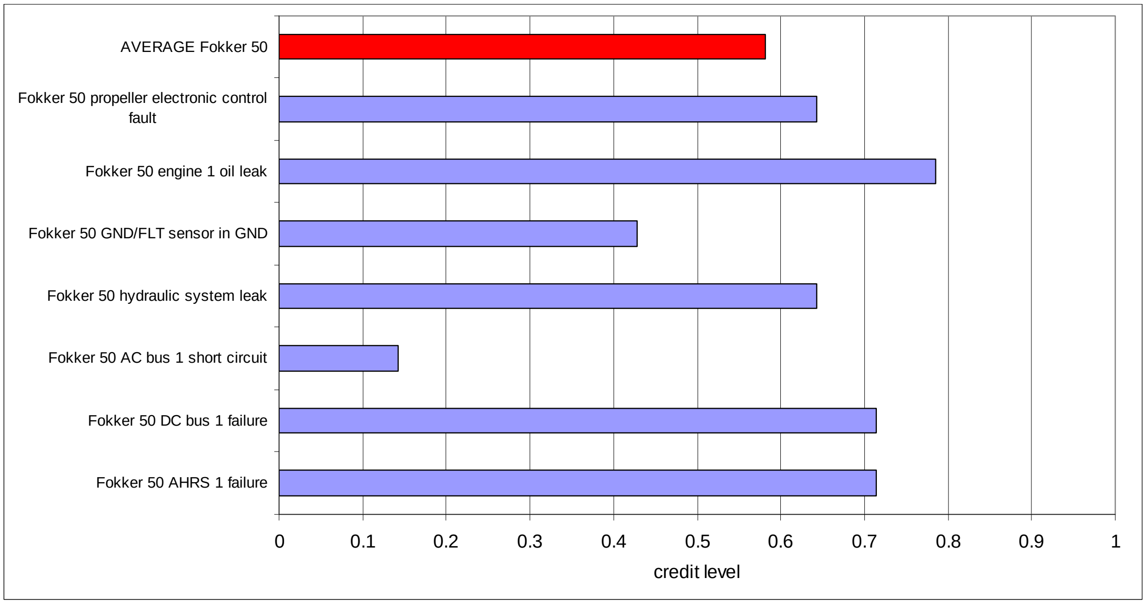

Figure 5. Fokker 50 Results

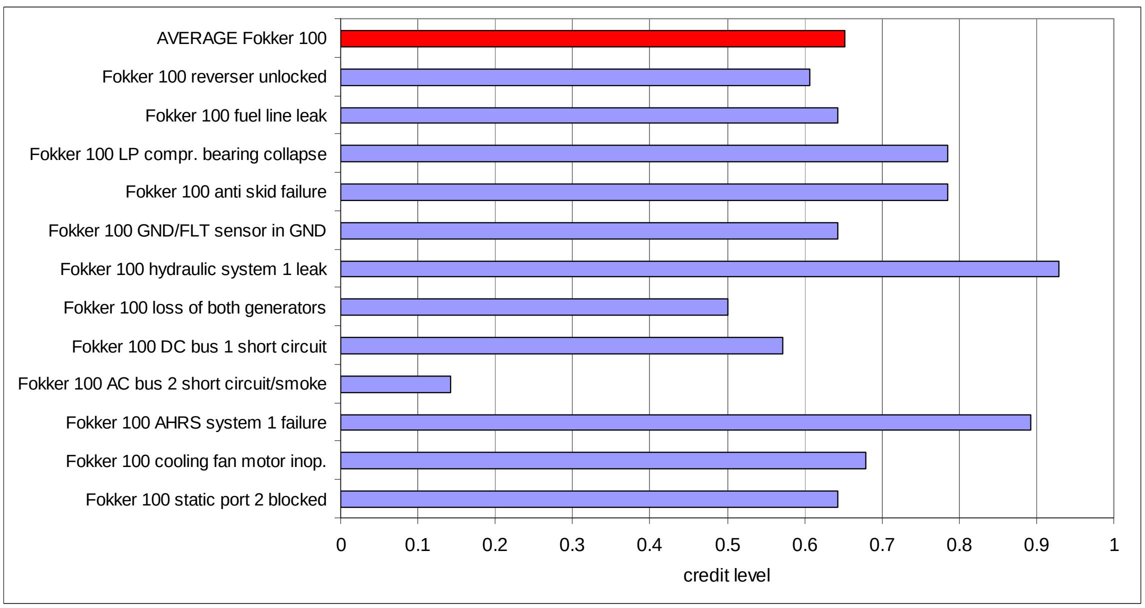

Figure 6. Fokker 100 Results

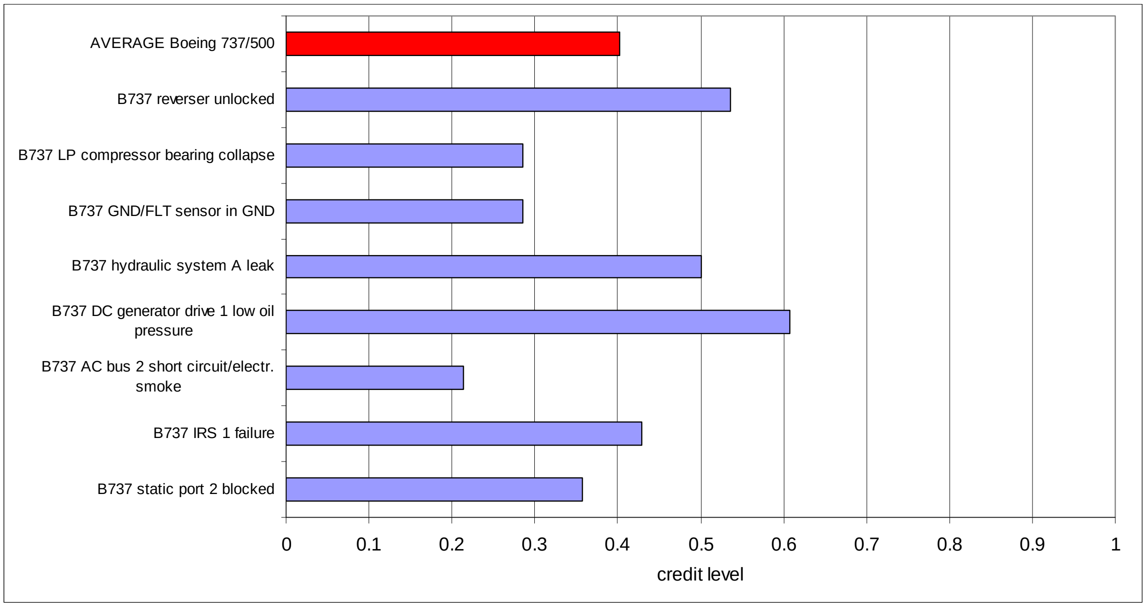

Figure 7. Boeing 737-500 Results

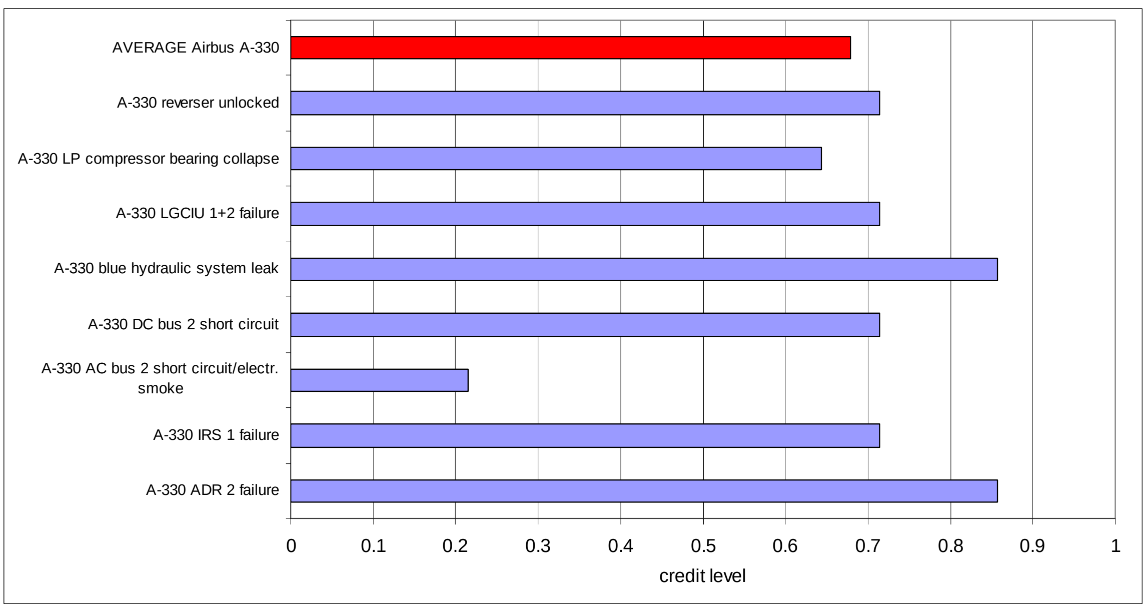

Figure 8. Airbus A330 Results

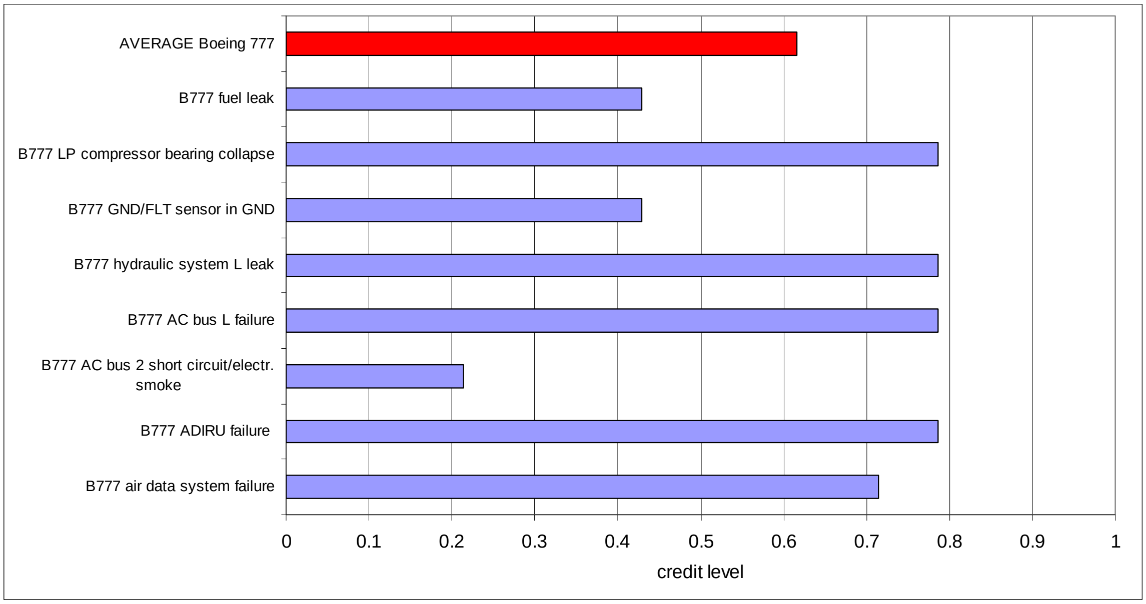

Figure 9. Boeing 777 Results

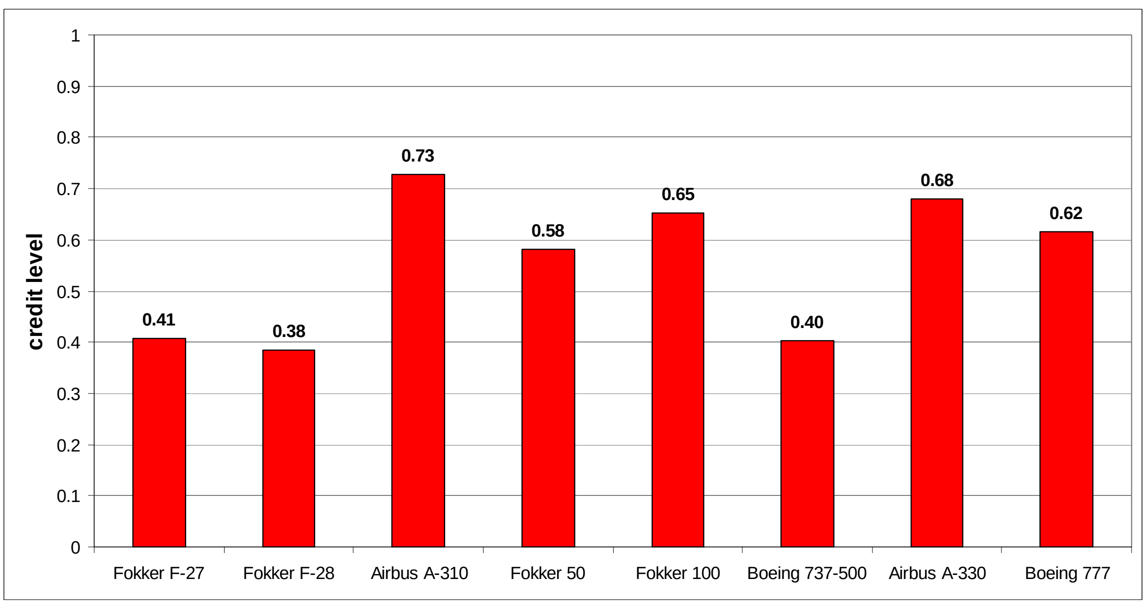

Figure 10. Average Credit Levels for Different Aircraft Types

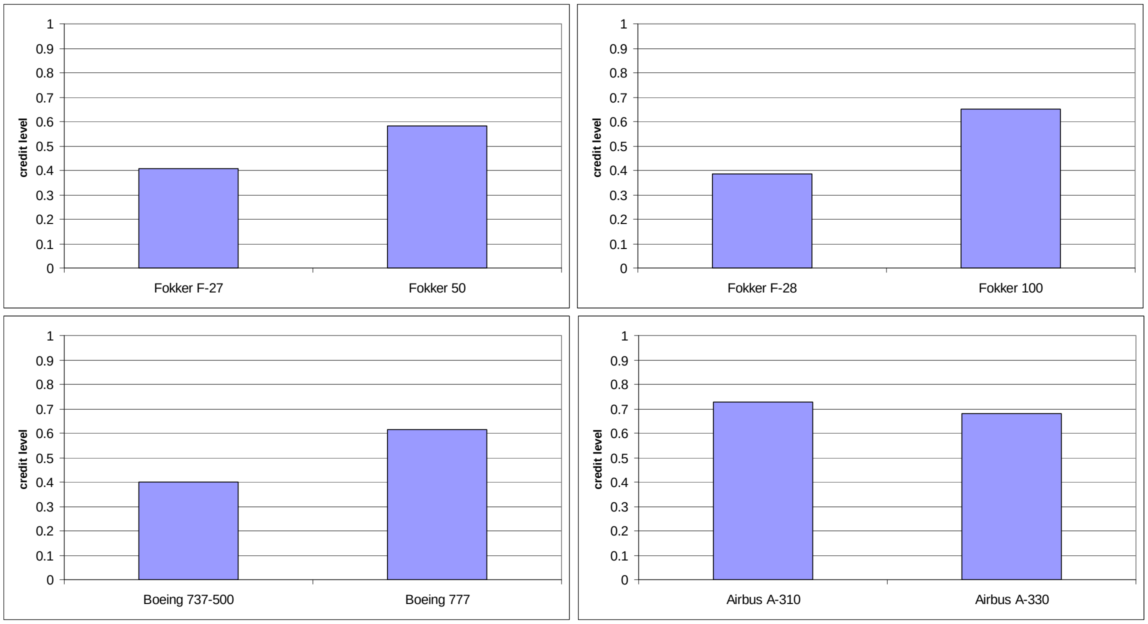

Figure 11. Average Credit Levels for Different Aircraft Types, Grouped by Manufacturer

3.3.2 Discussion of the Results.

It must be emphasized that the resulting scores should not be interpreted as quality ratings for flight decks. The scores represent the proposed amount of flight crew credit in the context of an SSA.

The results show that the method differentiates individual failures. For each aircraft type, the failure case with the least amount of credit is electrical smoke. In most aircraft, this is an unannunciated failure, which partly explains the low credit levels. The exception is the Airbus A310, which is equipped with an avionics smoke detector and obtains a credit level above 0.5 for this failure. However, this result is only valid under the assumption the avionics smoke detector is 100% effective in detecting all cases of electrical smoke. While this is unlikely without any detailed information on the system and its operational performance, the overall assumption of 100% effectiveness of annunciators was made.

None of the cases obtained the maximum credit level of 1.0. According to this result, there is still room for flight deck improvement, even for the most modern designs. Most cases scored particularly low on guidance with respect to the appropriate sequence of events (characteristic 8) and an immediate feedback after an inappropriate action is made (characteristic 9).

When comparing the average results for different types of aircraft, it should be noted that these average scores are based on only eight failure cases per aircraft. The average score is therefore not necessarily representative of the quality of the cockpit. Furthermore, the failure cases were not exactly identical for each aircraft type, which also complicates comparisons. Nevertheless, some interesting observations can be made.

Figure 11 shows the average results for each manufacturer separately; in each case, the older aircraft is on the left and the newer aircraft is on the right. The results show that all manufacturers obtain a higher score for their newer aircraft, with the exception of Airbus, where the score for the A310 and A330 are similar. This result is fairly consistent with a result from a previous phase (Roelen and Wever 2002) indicating a higher percentage of inappropriate flight crew responses to system failures for older generation aircraft as compared to newer generations. Comparison of the average score across manufactures is presented in figure 10; again, the oldest aircraft is on the left and the newest aircraft is on the right side of the figure. Perhaps surprisingly, the method does not produce higher credit levels for the generation 4 aircraft (Airbus A330 and Boeing 777) compared to the generation 3 aircraft (Fokker 100, Fokker 50, Boeing 737-500, and Airbus A310). The high average score for the Airbus A310 can be explained by the relatively high score for the electrical smoke case, as explained above. The low score for the Boeing 737-500 is also notable. Although this is a generation 3 aircraft, its score agrees with that of earlier generations. This result may perhaps reflect that the Boeing 737-500 is a development of the Boeing 737-100 and -200, which are generation 2 aircraft. Although the Boeing 737-500 is equipped with a newer cockpit and, particularly, with Cathode ray tubes instead of some electromechanical instruments, much of the system logic is the same as in the older Boeing models.

The scores for the Boeing 777 and Airbus A330 must be treated with some caution. These aircraft are equipped with very complex integrated digital systems and from the information available to the authors (the Aircraft Flight Manual and Aircraft Operating Manuals), it was sometimes difficult to determine how a particular failure would manifest itself.

3.3.3 Numerical Accuracy.

The results in appendix B section B.9 and figure 10 are presented as numbers with two decimal places, which suggests a certain numerical accuracy and a level of precision of the calculation method. This is somewhat misleading. Strictly speaking, the measurements are ordered against an ordinal scale, and the results are nothing more than a relative rank order. To avoid misinterpretation of the data, it might be more efficient to categorize the results into five different grades, ranging from poor to excellent. However, any decision on categorization will require insight into the raw results; at this stage of development, it was considered most prudent to present those raw results rather than processed data.

3.4 SIMULATOR EXPERIMENT.

The objective of the simulator sessions was to observe system failure handling by a non-type-rated flight crew member and to compare observations with results from applying the method described in section 3.3 to check whether observations regarding failure handling and flight deck design matched the assumptions on design characteristics on which the method is based. In particular, the way in which the flight deck design supports the flight crew in failure handling spurred much interest.

3.4.1 Set Up of the Experiment.

All experiments were conducted in a Fokker 100 level-D training flight simulator. Four experiments were conducted, each involving a different experiment pilot. All experiments included 2 hours prebriefing, 3.5 hours simulator time, and 1 hour debriefing. The Fokker 100 was selected to allow comparison of the simulator results with the paper analysis (section 3.3) and the results from the matrix sessions (section 3.5). The objective of the experiment was primarily to observe how the design of the flight deck supports the flight crew in failure handling. From previous studies, it is known that flight crew response to system failures is influenced by many factors. Flight deck design is important, but so are training, experience, and mental and physical conditions, as well as the documentation design. To eliminate the effect of type training as much as possible, it was decided to run the experiment with pilots who were not Fokker 100 type rated. All experiment pilots were experienced in multicrew, multiengine aircraft operations. One of the pilots did not have experience in glass cockpit aircraft; this was done purposely to investigate whether glass-cockpit experience resulted in different outcomes.

The experiment pilot occupied the RH seat, and was either pilot flying or pilot not-flying, depending on the particular failure case that was presented. The experiment pilot did not know which failures were going to be presented. He was, however, fully aware of the purpose of the experiment. The left-hand (LH) seat was occupied by the project pilot. All three project pilots participating in the experiment were skilled experiment pilots with significant experience on the Fokker 100. The project pilots performed part of the preflight briefing, and assisted the experiment pilot in the cockpit with many practical aspects such as seat adjustment and Flight Management System (FMS) programming. The project pilots were instructed not to provide cues on which action to take when a system failure occurred. They were allowed, however, to assist the experiment pilot, if explicitly requested, in performing tasks. For instance, the project pilot was frequently asked to take over the controls while the experiment pilot performed the required checklist items.

The simulator crew included two observers and one simulator operator. The observers took notes and provided a short debriefing after each failure case. One observer also provided the introduction during the pre-experiment briefing and chaired the debriefing after the experiment. The task of the simulator operator was to load the correct initial conditions prior to each failure case and to initiate the failure. An overview of the position of each participant during the experiment is presented in figure 12.

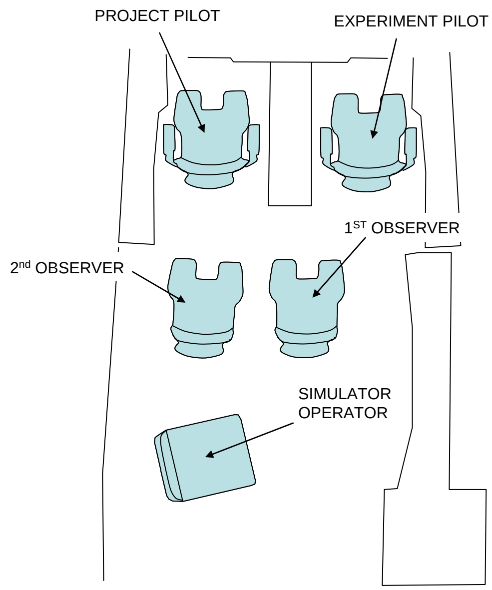

Figure 12. Overview of Simulator Seating Arrangement

The preflight briefing started approximately 2 hours before the beginning of the simulator session and was attended by the experiment pilot, the project pilot, the two observers and the simulator operator. The briefing started with a short introduction of all participants, followed by an overall introduction of the project, and an explanation of what was expected from all of the participants. The experiment pilot was explicitly asked to communicate his thought process during the failure handling and to emphasize any observations on flight deck design characteristics such as the clarity of failure messages, operability of controls, and the quality of the feedback provided by the aircraft. The experiment pilot was reminded that the objective of the experiment was not to see how fast he could solve the problem, or to rate him as a pilot. The project pilot then provided a brief Fokker 100 cockpit familiarization, using large pictures of the cockpit that were available in the briefing room (see figure 13). The objective was to indicate the basic design philosophy and concept of the Fokker 100. Specific attention was paid to the following topics:

- Dark and silent cockpit concept
- General layout of the overhead panel
- The use of the multifunction display system (MFDS) and Quick Reference Handbook (QRH) is case of annunciated failures
- The use of the QRH in case of non-annunciated failures
- The difference between the three alerting level: advisory, caution, and warning
- The use of multifunction display unit (MFDU) control panel

Figure 13. Preflight Briefing

3.4.2 Selection of the Failure Cases.

For each of the four simulator sessions, a set of failure cases was prepared. These failure cases were selected so that each session involved simple and more complex failures, different flight phases, and different systems. The list of failures was known to all participants but the experiment pilot.

3.4.3 The Experiment.

The experiment was conducted in a Fokker 100 level-D training simulator at CAE in Hoofddorp, The Netherlands (figures 14 and 15). All experiments were performed under simulated daylight conditions. The motion system was engaged, and a video camera recorded the actions of both pilots. Each session started with a takeoff in which the experiment pilot was pilot flying. When the experiment pilot was sufficiently familiar with the aircraft (typically after 10-15 minutes), the first failure was presented. When the failure handling was completed, a short debrief was conducted by the observers. During the debriefing, the simulator operator prepared the simulator for the next failure case. Each simulator session lasted 3.5 hours, which included a short break approximately halfway through the session.

Figure 14. Simulator Used for the Experiment

Figure 15. Starting the APU During the Simulator Experiment

After each session, an overall debrief of the experiment was conducted. During this debrief, the team ran through all individual failures cases and discussed any topic that had not yet been addressed during the experiment itself. The experiment pilot was then asked to provide general comments on the flight deck design and those characteristics that positively or negatively influenced his failure handling. All participants were asked whether there was any way in which the prebriefing or the experiment itself could be improved.

3.4.4 Results.

Detailed results of the simulator experiments are provided in appendix C. Overall, it was concluded that the setup of the experiment was successful. Failure handling by a non-type-rated pilot in a controlled environment provided much insight into the way in which the flight deck supports detection, decision and mitigating action following aircraft system failures. The following observations are considered particularly relevant for this study:

- Feedback is important. This concerns feedback on the overall status of the aircraft as well as immediate feedback on each individual action. An example from the experiment of a lack of feedback was exhibited when starting the auxiliary power unit (APU). The APU switch on the overhead panel must be rotated to START. Initially, there is no apparent result: no light indication, no change of the APU parameters. Feedback in the form of a rising APU exhaust gas temperature (EGT) occurs only after approximately 10 seconds. As a result, some pilots concluded they were doing something wrong and attempted to restart the APU.

- Consistency in designations is essential. There were a few examples during the experiment of procedures whose designation on the MFDU was slightly different than in the QRH or where labels on the flight deck differed slightly from the checklist. The most confusing situation during the experiment was a loss of both engine generators. This resulted in the red AC SUPPLY light on the standby annunciator panel to come on, but the procedure was listed under the heading LOSS OF BOTH ENGINE GENERATORS in the QRH.

- Despite the low stress levels (the experiment was intentionally conducted in a relaxed atmosphere, most flights were conducted in simulated visual meteorological conditions without turbulence, there was no other traffic and no air traffic control (ATC)) it was observed how quickly pilots became distracted from the task of flying the aircraft in trying to complete a particular part of the procedure. The clearest example evident during the experiment was during the manual rudder limiter procedure as part of some electrical procedures. The experiment pilots were unfamiliar with this type of procedure, which involved setting some switches on the overhead panel. Since the switches are not easily located, some pilots got quite distracted searching for them.

- Despite the effort of engineers to design thorough procedures in a desktop environment, pilots can and will deviate from procedures. For instance, this was demonstrated during the simulated inadvertent (uncommanded) unlocking of the thrust reverser, after which, one of the pilots decided to shut down the engine, contrary to the prescribed procedure.

- Airlines have the freedom to adapt the Aircraft Flight Manual (AFM) according to their operational needs. The difference between the AFM and the Aircraft Operating Manual (AOM) created some confusion during the experiments; e.g., when the procedure on the display did not correspond exactly with the procedure in the manual. This is a potential source of flight crew error for which a regulatory safety net currently does not exist.

The experiment confirmed the importance of the design characteristics listed in appendix A, and the results of the experiment give no reason to adapt that list.

3.5 MATRIX SESSIONS.

3.5.1 Description.

The objective of the matrix sessions was to understand the logic used in deciding flight deck design with respect to failure handling. The setting in which this was done was a re-enacting of the 'matrix sessions' that took place at Fokker aircraft during the development of the Fokker 100 in the early 1980s. A matrix sessions report is included in appendix D.

3.5.2 Conclusions From the Matrix Sessions.

The matrix sessions cover similar issues as those on the list of design characteristics (appendix A), albeit less systematically. While the brainstorm approach, as followed during the matrix sessions, surely has its merits, it is believed that similar sessions by aircraft manufacturers would benefit from applying a systematic method, like the one developed in this project, as a complement—not a replacement—to existing methods.

Technology was sometimes a limiting factor in designing the flight warning computer of the Fokker 100. While the system designers were aware of the desire to have particular features at that time, it was not possible to incorporate those due to lack of technology.

Even with a group of subject matter experts, including experiment pilots, in a desktop environment, it is difficult to predict the behavior of flight crews. In the case of a blocked static port discussed during the matrix session, consensus among participants was that this would be noticed by the pilot flying immediately after takeoff as the altimeter indicated ground level. However, the simulator experiment demonstrated otherwise.

The matrix sessions were very useful in providing a realistic view on the type of considerations being made during the development of the flight deck and system failure-handling procedures.

Generally speaking, the matrix sessions did not reveal any particular characteristic that was not on the proposed list of key design characteristics. The matrix session confirmed the importance of the items on the list.

4. CONCLUSIONS AND RECOMMENDATIONS.

A method has been developed that combines flight deck characteristics into a level of certification credit for flight crew intervention in case of system failures. The method is easy to apply, provided that the system failures modes and associated flight deck annunciations are known. The time needed to determine the amount of flight crew intervention credit for a single aircraft and failure case combination depends on the complexity of the system and the associated failure, and the familiarity of the analyst with the system involved. In these analyses, where the analysts had only limited pre-existing knowledge of the aircraft systems, application of the method required approximately 1 to 2 hours per failure case. Application of the method is expected to take only 10-15 minutes per failure case if the analysts are familiar with the systems involved, as might be expected during application of the method as part of the aircraft's type certification process.

The simulator experiment and the matrix sessions confirmed the importance of the key characteristics that are the backbone of the scoring method. The simulator experiment and the matrix sessions did not reveal any omissions on that list of characteristics.

Application of the method to a number of sample cases shows that, as intended, it produces a higher score for more modern flight decks. The most modern aircraft in the sample cases (Boeing 777 and Airbus A330) did not obtain the maximum possible score, indicating that there is still room for improvement, even for those aircraft.

As results of phase 1 of this study have shown, a method for determining realistic levels of flight crew intervention credit in system safety assessments could result in significant flight safety improvements. While every possible effort was spent in making this a valid, practicable, and acceptable method, it is still the result of a research project. Therefore, it is recommended for consideration that the Aviation Rulemaking Advisory Committee (ARAC) be informed of the results of this study so that under the guidance of ARAC, this method can be further developed.

The simulator experiment demonstrated the confusion when the Aircraft Operating Manual (AOM) is differs from the Aircraft Flight Manual (AFM). It is therefore recommended to initiate an investigation into possible ways to prevent the allowable differences between the AFM and the AOM that result inflight crew errors.

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APPENDIX A—LIST OF DESIGN CHARACTERISTICS

1. Is the system failure reliably, explicitly and timely indicated to the flight crew by means of an aural and/or visual and/or tactile alert?

   ☐ Yes
   ☐ No

   Explanatory notes

   The single key design characteristic that facilitates detection of a system failure is its explicit annunciation. Other failure cues, such as inherent cues and aircraft motion cues, may be ambiguous, may be untrained and may even disrupt proper failure detection and handling. Non-explicit failure indication on normal instruments also appears to be of fairly low importance for detection.

   Reliably means that the system should not produce nuisance alerts. The primary purpose is to maintain the crew's confidence in the alerts, so that they respond properly to each alert. If nuisance alerts are common, the danger is that flight crews may ignore or cancel alerts by habit, even when they are not nuisance alerts.

   Explicitly means that the failure is indicated by a dedicated alert in order to draw the attention of the crew. The applicant should demonstrate that the alert can be detected by the flight crew and can be discerned as an alert.

   Timely means that the failure indication should occur when the aircraft's capability and the flight crew's ability still remain for effective flight crew action. Note that timeliness may depend on particular circumstances, such as the flight phase.

   Example

   An illuminated master caution light is an explicit alert, while a pointer in the red band on an engine instrument is not.

2. Does the system failure manifest itself to the flight crew through inherent cues and/or aircraft motion cues?

☐ Yes
☐ No

Explanatory notes

Inherent cues are defined as cues other than designed failure annunciation cues or instrument indications. Examples of inherent cues are vibration, odor, visible sparks, smoke, and sounds. In addition, a system failure can manifest itself to the flight crew through aircraft motion cues. Motion cues are defined as yawing, rolling, or pitching motions.

In many cases there will be combinations of cues. Some cues may be very subtle and others can be quite upsetting. Flight crew attention can easily divert to the most salient cue, especially since flight crew may never have experienced similar situations in operations or (simulator) training. Inherent cues and aircraft motion cues are quite often ambiguous. An example is a loud bang, which can be the result of any type of explosion such as severe engine trouble, a burst tire, or another cause.

The applicant should analyze whether inherent and/or aircraft motion cues may result from the system failure.

3. Does the system establish suitable priorities, does it vary the level of urgency and does it inhibit alerts depending on the flight phase and current aircraft condition and configuration?

☐ Yes
☐ No

Explanatory notes
Suitable priority, level of urgency and inhibition of alerts are important factors when credit is sought for flight crew intervention. This characteristic corresponds to operational requirement 3.1.3 of SAE ARP 4102/4 "Flight Deck Alerting Systems (FAS)."

A single system failure may cause related or associated (sub)systems to fail or may affect operation of associated (sub)systems. Simultaneous failures may also be completely independent. In both cases, multiple alerts may be generated; that is, presentation of two or more approximately simultaneous alerts for different systems or subsystems.

The applicant should demonstrate that the flight deck alerting system establishes priorities in case of multiple alerts. The application should also demonstrate that the alert corresponding to the system failure has the proper level of urgency (Warning, Caution, Advisory or Information) and is properly inhibited. Priority, level of urgency, and inhibition may depend on the flight phase and the aircraft's condition and configuration.

Example 1
When an engine failure results in a master warning light and the text message "engine failure," it is not regarded here as multiple alerts because it involves a single system (engine). When an engine failure results in a warning light, the text message 'engine failure' and the text message 'electrical system 1 off', this is regarded as multiple messages because it involves two systems (engine and electrical).

Example 2
Failure annunciations should normally not lead to a rejected takeoff when the aircraft is above the takeoff decision speed (V_1), and consequently, most alerts are normally inhibited during the takeoff roll at speeds above 80 kts.

4. Does the system remove incorrect or potentially misleading information?

- ☐ The failure does not produce incorrect or potentially misleading information.
- ☐ Yes, incorrect or potentially misleading information is completely removed.
- ☐ No, incorrect or potentially misleading information is not or only partly removed.

Explanatory notes

A system failure could lead to the display of incorrect or potentially misleading information. The system should actively remove such information. When the information is not removed, the flight crew may continue using it, with potentially catastrophic results.

The applicant should demonstrate whether the failure produces incorrect or potentially misleading information. In case such information is produced, the applicant should demonstrate that the affected parameters are removed from all displays and indicators.

Example

When an aircraft attitude information source becomes unreliable, the corresponding attitude indications should be removed. Putting a failure flag near or on the affected information is not enough, since people tend to continue using the information.

5. Are unambiguous system condition message(s) presented to the flight crew?

☐ Yes
☐ No

Explanatory notes
System condition awareness is improved when the alert includes information that supports an understanding of the nature and location of the system failure condition. A system condition message is defined as a message that informs the flight crew about the system failure or abnormal operating condition.

An unambiguous system condition message states with clarity the nature and location of the problem (ARP 4102/4) so that a direct and unique relation exists between the failure and the system condition message. A unique relation is established when each system condition message identifies a distinct failure condition.

Example
A message like "HYD SYS L LEAK RSVR 1" identifies the name of the failed system ("HYD SYS L"), the fact that the system has a failure ("LEAK"), as well as the nature of the failure: a leak in the reservoir number #1 ("LEAK RSVR 1").

6. Is the corrective or compensatory procedure presented to the flight crew?

- ☐ Yes, the procedure is completely and automatically presented on a display.
- ☐ No, the required procedure is prompted but not automatically presented.
- ☐ No, the procedure is neither prompted nor automatically presented.

Explanatory notes

The applicant needs to evaluate in what way the required corrective procedure is presented to the flight crew. The first option refers to the automatic presentation of the entire corrective procedure or a part of the corrective procedure on a display. The procedure may be presented automatically or after action by the flight crew, e.g., after pushing a key.

Prompting is defined as providing an indication about how and where to find the procedure to be performed. This information can be presented on a display by means of for example a reference to a manual or handbook page where the corresponding procedure can be found, or by means of a specific failure title that can be matched with a specific procedure in a handbook or manual.

Manuals or handbooks include the Abnormal Procedures checklist, Quick Reference Handbook, AFM, and the Aircraft Operating Manual. Manuals or handbooks can be in either electronic or on paper.

Example

The ECAM in the Airbus A320 automatically presents the required flight crew actions in case of a system failure.

7. How is the attention-drawing feature deactivated?

☐ The attention-drawing feature can be deactivated by the flight crew.
☐ The attention-drawing feature will be deactivated automatically after a certain time span.
☐ The attention-drawing feature will be deactivated automatically only after crew action has been successfully completed or the failure has been corrected.

Explanatory notes
Both aural and visual attention-drawing features are considered here, such as an attention and central warning lights on the instrument panel in front of the pilot. This characteristic addresses only attention-getting features. Alert messages are not considered here.

An attention-drawing feature is a design characteristic to alert the crew of a system failure or an emergency or abnormal system operating condition, such as an aural alert or an alert light.

The crew action is considered to be successfully completed when the system failure condition has been mitigated or compensated.

8. Does the system provide guidance with respect to the appropriate sequence of actions in the procedure?

☐ Yes
☐ No

Explanatory notes
This design characteristic refers to the presentation of cues that assist the flight crew to execute the actions in the procedure in the appropriate sequence. Guidance may, for instance, be provided by visual cues such as illumination of controls or color coding of the appropriate action from a procedure on the display.

In order to direct the flight crew to the appropriate control that has to be operated, the control can be highlighted. Highlighted means that the control can easily be identified as the one that has to be operated. This characteristic is sometimes referred to as hand-guidance, because the hand of the pilot is guided towards the correct control by means of a (visual) cue.

This design characteristic may help the flight crew to maintain situational awareness, reduce the workload and minimize the probability of error when executing a number of actions under conditions that may involve high workload.

Example
An example of highlighting is illumination of the engine fire pushbutton corresponding to the affected engine in case of an engine fire.

9. Does the system provide immediate feedback to the flight crew after an inappropriate action is made?

☐ Yes
☐ No

Explanatory notes
Inappropriate action can be an inappropriate operation of the correct control, or operation of the wrong control. The latter may be caused by out-of-sequence execution of actions in the procedure or skipping of actions.

The applicant must show that the system logic can detect inappropriate actions.

10. Does the procedure contain if-then statements?

- ☐ Yes
- ☐ No

Explanatory notes

If-then statements are conditional expressions. They require evaluation of a particular condition and a subsequent flight crew decision based on the result of that evaluation. Generally speaking, if-then statements in a procedure will increase workload, in particular when nesting of if-then statements occurs.

11. Does the procedure contain one or more action(s), which require a continuous operation and/or monitoring of controls to such a degree that these action(s) jeopardize other operating and/or monitoring tasks?

- ☐ Yes
- ☐ No

Explanatory notes
The cockpit is a typical multitask environment, with many tasks running in parallel. Some failure mitigation procedures require continuous monitoring of certain indications; other procedures require continuous operation of certain controls. These tasks may draw too much of the flight crew's attention, and as such, they can jeopardize the other cockpit tasks.

Example
In many aircraft, the procedure for manual cabin pressure control requires continuous monitoring of pressurization instruments.

12. Does the system provide feedback with respect to the system condition during and after completion of the corrective or compensatory procedure?

- ☐ Yes
- ☐ No

Explanatory notes

Feedback is defined as information about the current system condition, and includes the failure condition. This design characteristic covers the degree to which the system enables the flight crew to observe or assess the result of their corrective actions after they have completed the required corrective actions. The applicant must show that the feedback provided to the flight crew is unambiguous.

Example

In case of a hydraulic failure on the Boeing 737-400, the flight crew is required to put the flight control switch to STBY RUD. This deactivates the flight control LOW PRESSURE light, although the pressure in the system is still low. The failure still exists but is not indicated any more. In this case, the feedback information is ambiguous.

13. Does the system automatically prompt deferred actions at the appropriate moment, and does it automatically display information that must be remembered as a result of the failure?

☐ Yes
☐ No

Explanatory notes
Some failure mitigation procedures require actions that must be performed when certain conditions are fulfilled or when a certain amount of time has past. Other procedures may require the flight crew to remember certain information.

When deferred actions are not prompted or when relevant information is not automatically presented, successful flight crew intervention depends on the human memory. Especially under abnormal conditions, this may be a weak point.

Example
Examples of recall of remembered data or information are memory items and speed restrictions under certain conditions.

14. Is feedback on the control input provided?

☐ Yes
☐ No

Explanatory notes
This refers to information to the flight crew on the fact that indeed the control position has changed after the action. This feedback can be straightforward, as in the case of a toggle switch. It can also involve a light in a pushbutton, a color change after selecting an item with a cursor control device, etc.

Note that visual feedback implicates that it is visible by both crew members.

APPENDIX B—APPLICATION RESULTS

The following sections provide a detailed description of aircraft type failure case combinations that have been analyzed for the purpose of this study. Each of the cases includes a description of the failure, the failure manifestation, the required crew procedure as per Aircraft Operations Manual (AOM), a description of the required flight crew action, information on alert inhibition, information on possibly incorrect or misleading information that may appear as a result of the failure, and a description of (failure) manifestations after completion of the procedure. In all cases, canceling the aural alerts and the master caution and warning light is considered normal crew action and is not specified in the procedures or the description of crew action. Section B.9 of this appendix summarizes the results of the analysis in a tabular format, showing how each combination of aircraft type and failure case scores according to the list of key characteristics in appendix A.

B.1 FOKKER 100.

Aircraft type: Fokker 100
Failure case: Blocked static port, right-hand system.
Failure manifestation: Left and right airspeed and altitude indications on EFIS differ.
If left and right airspeed indications differ by more than approximately 10 kts: Double chime, Master caution light amber flashing, COMPARE SPEED message in amber on the MFDU.
AOM Procedure:

```
COMPARE SPEED ALERT
EFIS INDICATIONS..........................COMPARE WITH STBY INSTR
If required:
AFFECTED SOURCE..................................SELECT ALTN SYS
```

Alert inhibition: First engine on-TO power, 80 kts-Liftoff, Touchdown-last engine off.
Incorrect or possibly misleading information:
Incorrect airspeed on RH EFIS.
Incorrect altitude on RH EFIS.
Incorrect vertical speed on RH EFIS.
Description of required action: Compare left EFIS speed indication, right EFIS speed indication and standby speed indication. Determine which speed indication is deviating (left or right). Push ADC select pushbutton on the deviating (affected) side. Pushbutton is located on main instrument panel.
Manifestation after correct completion of procedure: ADC source select pushbutton on affected side has illuminated amber ALTN caption. No difference between LH and RH altitude, speed and vertical speed indications.

Aircraft type: Fokker 100
Failure case: Hydraulic system 1 leak in tank.
Failure manifestation: System 1 tank quantity display on hydraulic panel (located on the overhead panel) will display decreasing fluid quantity: Quantity is numerically displayed in percentage of maximum tank capacity. When the level is below 37 percent the LO QTY light for system 1 will illuminate amber on the hydraulic panel. Double chime. Master caution light illuminates amber on the glareshield panel. An HYD SYS 1 LO QTY message appears in amber on the MFDU. Aileron forces increase to approximately two times the normal values.
AOM procedure:

```
HYDRAULIC SYSTEM 1 LOW QUANTITY
SYS 1 ENG AND 2 PUMP..........................................OFF
HYDRAULIC SYSTEM 1 FAIL PROC................................APPLY
STATUS:   Flight controls single channel
          Normal flap inoperative
          Normal gear inoperative
          Speed brake inoperative
          Reversers inoperative
          Hydraulic system 1 low quantity
```

Alert inhibition: 80 kts-400ft, 1000 ft-80 kts.
Incorrect or possibly misleading information: No incorrect information displayed.
Description of required action: Push ENG 1 PUMP and ENG 2 PUMP for system 1. Pushbuttons are located on hydraulic panel on the overhead panel.
Manifestation after correct completion of the procedure: Aileron forces are approximately two times normal. ENG 1 PUMP and ENG 2 PUMP pushbuttons for system 1 have illuminated white OFF caption. LO QTY light for system 1 will remain illuminated on hydraulic panel. MFDS will display status:

Flight controls single channel
Normal flap inoperative
Normal gear inoperative
Speed brake inoperative
Reversers inoperative
Hydraulic system 1 low quantity

Aircraft type: Fokker 100
Failure case: Ground and flight switch remains in ground mode after liftoff.
Failure manifestation: Landing gear selector blocked in down position. If the aircraft is above 400 ft radio altitude: Double chime, amber Master caution light amber, GRD and FLT CONTROL message in amber on the MFDU.
AOM procedure:

```
LANDING GEAR SELECTOR BLOCKED IN DOWN POSITION
SPEED.................................................MAX 200 kt
If no GND/FLT CONTROL alert is displayed above 400 ft AGL
     LG OVRD...............................................DEPRESS
     LG SELECTOR...............................................UP
If GND/FLT CONTROL alert is displayed:
     DO NOT RETRACT LANDING GEAR
     SERVICES CONNECTED TO THE GND/FLT CONTROL MAY BE AFFECTED
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Incorrect position on the FMS (remains position at the beginning of the runway).
Description of required action: No action required.
Manifestation after correct completion of the procedure: Landing gear selector is in down position. When a GND and FLT CONTROL alert is displayed, amongst others, the following services may be affected:

- Cabin pressurization
- Stall protection
- Lift dumper auto disarming after liftoff
- Wing and/or tail anti icing
- MFDS (no flight phase inhibition, no procedures display)
- FMS (no aircraft position prediction)
- EFIS (V_{SS} and V_{MA} not displayed)
- ATC transponder(s)

Aircraft type: Fokker 100
Failure case: DC bus 1 short circuit.
Failure manifestation: Possible smell of burning, electrical smoke.
Double chime, master caution light amber flashing, DC BUS 1 FAULT in amber on MFDU.
DC bus voltage zero on electric display on the overhead panel (if display selector switched to DC bus and VOLT pushbutton selected)
Left-hand fuel tank indication inoperative, left-hand oil pressure indication inoperative, hydraulic quantity indication #1 displays “0”.
AOM procedure:

```
DC BUS 1 FAULT
DO NOT X-TIE
BUS EQUIPMENT LIST..........................................CHECK
MAN RUD LMTR PROC...........................................APPLY
AVOID ICING CONDITIONS
```

Alert inhibition: 80 kts-400 ft, 400 ft,-80 kts.
Incorrect or possibly misleading information:
Hydraulic quantity indication #1 displays “0”.
Description of required action: Application of manual rudder limiter procedures requires depressing the RUDDER LIMITER pushbutton (located on the flight augmentation panel on the overhead panel). Then the SPEED pushbutton must be switched to either low speed mode or high speed mode, depending on the flight speed.
Manifestation after correct completion of the procedure: DC BUS 1 FAULT in amber on MFDU. Rudder limiter pushbutton has illuminated white MAN caption. SPEED pushbutton will have illuminated white caption, either HI or LO. Left-hand fuel tank indication inoperative, left-hand oil pressure indication inoperative, Hydraulic quantity indication #1 displays “0”.

Aircraft type: Fokker 100
Failure case: Failure of avionics cooling blower fan # 1, # 2, and # 3.
Failure manifestation: Single chime, AVNCS COOL INOP in amber on the MFDU. Illumination of the white EFIS EMER COOL FAN light on the avionics panel on the overhead panel. RH EFIS and both MFDS DU's fail after approximately 15 minutes.
AOM procedure:

AVIONICS COOLING INOPERATIVE

```
AVNCS COOL INOP PROC........................................APPLY
```

AVIONICS COOLING INOPERATIVE PROCEDURE

```
STBY ANN PANEL............................................BACK UP
STBY ENG IND...................................................ON
EFIS EMER COOL FAN LIGHT....................................CHECK
```

- If light is on:
  LH EFIS DU's remain operative
  Expect failure of RH EFIS and both MFDU's after approximately 15 min.
- If light is not on:
  Expect failure of all EFIS DU's and both MFDS DU's after approx 15 min.

Alert inhibition: TO power-1000 ft, 1000 ft- 80 kts
Incorrect or possibly misleading information: No incorrect information displayed.
Description of required action: Manual selection of the Standby Annunciator Panel by depressing the WARN SYS BACKUP pushbutton at the standby annunciator panel on the main instrument panel. Switching on the Standby Engine Indication with the SEI ON/OFF toggle switch on the standby Engine Indicator Panel on the main instrument panel. Verify illumination of the EFIS emergency cool fan light on the overhead panel.
Manifestation after correct completion of the procedure: Illumination of white BACKUP caption on the WARN SYS BACKUP pushbutton at the standby annunciator panel. SEI toggle switch in ON position. Indications of EPR, TGT, N1 and N2 values on the SEI. AVNCS COOL INOP in amber on the MFDU. Illumination of the white EFIS EMER COOL FAN light on the avionics panel on the overhead panel. RH EFIS and both MFDS DU's fail after approximately 15 minutes.

Aircraft type: Fokker 100

Failure case: Attitude and heading reference system 1 failure.

Failure manifestation: Double chime, Master caution light. EFIS in amber on the MFDU. Amber ATT and HDG flags appear on the left-hand PFD, ATT initially flashing. Attitude sphere, roll pointer, roll scale, slip indicator, aircraft symbol, FD command bars or flight path vector and flight path target are removed from LH PFD. Heading marks and bugs are removed from the LH PFD. ATT and HDG source select pushbutton on the LH Source Select panel has amber FAULT caption illuminated. Source select panel is located on the main instrument panel.

AOM procedure:

```
EFIS FAULT
Source select...............................................CHECK
If required:
     Affected source..............................SELECT ALTN SYS
```

Alert inhibition: Central warning inhibited from 80 kts -400 ft and 400 ft - last engine off.

Incorrect or possibly misleading information: No incorrect or possibly misleading information.

Description of required action: Select alternate attitude and heading source by pushing ATT and HDG source select pushbutton on LH Source Select Panel.

Manifestation after correct completion of the procedure: ATT and HDG source select pushbutton on the LH Source Select panel has white ALTN caption illuminated.

Aircraft type: Fokker 100
Failure case: Non-annunciated AC bus 2 failure resulting in electrical smoke in the cockpit.
Failure manifestation: Electrical smoke.
AOM procedure:

```
ELECTRICAL SMOKE
OXY MASK/GOGGLES....................................AS REQUIRED
CREW COMMUNICATION....................................ESTABLISH
ESS + EMER PWR ONLY..........................................ON
SPEED.............................................MAX 250 kt/M.06
BUS EQUIPMENT LIST.......................................CHECK
AVOID AREAS OF SEVERE TURBULENCE
AVOID ICING CONDITIONS
MAN RUD LMTR PROC.........................................APPLY
LAND AS SOON AS POSSIBLE
SMOKE REMOVAL PROC (if required)............................APPLY
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: After selecting the ESS + EMER PWR ONLY pushbutton to ON several consequential failure alerts are displayed at the MFDU. The corresponding procedures should not be executed.
Description of required action: Depress the ESS + EMER PWR ONLY pushbutton on the Electric panel on the overhead panel. This pushbutton is guarded.
Manifestation after correct completion of the procedure: ESS + EMER PWR ONLY pushbutton has white illuminated ON caption. After selecting the ESS + EMER PWR ONLY pushbutton to ON several consequential failure alerts are displayed at the MFDU.

Aircraft type: Fokker 100
Failure case: Loss of both engine generators.
Failure manifestation: Loss of services, whole series of messages appears on the MFDU. The Standby Annunciator Panel (SAP) is automatically activated. The AC SUPPLY light illuminates red on the SAP. GEN 1 and GEN 2 pushbuttons on the overhead panel have amber illuminated FAULT caption.
AOM procedure:

```
LOSS OF BOTH ENGINE GENERATORS
GEN 1 and 2......................................OFF THEN ON
If no generator recovered:
     STBY ENG IND.........................................ON
     DESCENT........................................INITIATE
     APU,if available..................................START
     If no AC power restored:
          STBY ANN PANEL...............................BACK UP
          FUEL SUCTION FEED PROC.........................APPLY
          MANUAL CABIN PRESS CONTROL PROC................APPLY
          SPEED.................................MAX 250 kt/M.65
          AVOID AREAS OF SEVERE TURBULENCE
          AVOID ICING CONDITIONS
          LAND AS SOON AS PRACTICABLE
          SERVICES INOPERATIVE FOR LANDING:
          •  AUTOMATIC LIFT DUMPER EXTENSION
          •  ANTI-SKID
          •  THRUST REVERSERS
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Loss of both engine generators is a level 3 alert as indicated by the red AC SUPPLY light on the SAP. Level 3 alerts require immediate corrective or compensatory action by the flight crew. But the messages on the MFDU (like AC BUS 1 FAULT, AC BUS 2 FAULT, etc) appear in amber, indicating a level 2. Level 2 alerts require immediate pilot awareness and subsequent corrective or compensatory action. Absence of a level 3 warning indication on the MFDU may cause confusion.
Description of required action: First action is resetting both generators by pushing the GEN 1 and GEN 2 pushbuttons on the electric panel on the overhead panel to OFF and then to ON again. If no generator recovers the standby engine indicator panel is turned on by switching the SEI ON/OFF switch on the center main instrument panel to ON. A descent must be initiated and the APU started by rotating the APU start selector on the right lower overhead panel to START.
Manifestation after correct completion of the procedure: Depends on whether the APU is able to provide electric power. If the APU is not available the electrical system runs on battery power only. A fully charged battery will provide a minimum of 30 mins standby power.

Aircraft type: Fokker 100
Failure case: Uncommanded unlocking of the thrust reverser due to a failure of the selector valve relay.
Failure manifestation: Master caution light illuminates amber. Double chime. REVERSER ENG 1/2 message appears in amber on the MFDU. A green 'R' appears on both side of the relevant EPR tape on the MFDU. The thrust reverser feedback mechanism realizes automatic retardation of the associated throttle to the idle position. The autothrottle disconnects. Sudden deceleration and pitch change of the aircraft. Vibration and buffet.
AOM procedure:

```
REVERSER UNLOCKED
If thrust lever blocked at idle and/or pronounced buffet:
REVERSER UNLOCKED PROCEDURE.................................APPLY

REVERSER UNLOCKED PROCEDURE - INFLIGHT
SPEED...................................................VFTO
LIFTD (OVHD panel)......................................OFF
Cycle affected reverse thrust lever to idle reverse and back
to forward idle position
LIFTD (OVHD panel)......................................NORMAL
If alert persists:
     Use zero flap for approach and landing
     Apply LANDING WITH FLAPS LESS THAN 25 procedure.
```

Alert inhibition: 80 kts- 1000 ft, 1000 ft - touchdown.
Incorrect or possibly misleading information: No incorrect information.
Description of required action: The lift dumper system must be switched off by pressing the guarded LIFTD pushbutton on the hydraulic section on the overhead panel to the OFF position. The affected reverse thrust lever on the throttle must be cycled to idle reverse and back to forward idle. The liftdumper system must then be switched on again by pressing the guarded pushbutton.
Manifestation after correct completion of the procedure: A green 'R' appears on both side of the relevant EPR tape on the MFDU. The associated throttle remains in the idle position. Vibration and buffet remains.

Aircraft type: Fokker 100
Failure case: LP compressor bearing failure (engine 1).
Failure manifestation: Rapid decrease of N1 to 0. TGT increases rapidly. Loud bang, sudden high-frequency vibration, decreasing as N1 slows down. N2 goes to windmilling value, TGT slowly decreases to ambient temperature. Repetitive triple chime. Master warning light illuminates red. ENG 1 FAIL message in amber on the MFDU. Fuel lever light of engine 1 illuminates. Abnormal electric and hydraulic indications due to the inoperative engine.
AOM procedure:

```
ENGINE FAILURE
IGNITION..............................................RELIGHT
THRUST LEVER.............................................IDLE
If no immediate relight:
FUEL LEVER...............................................SHUT
IGNITION.................................................NORM
If damage:
FIRE HANDLE.......................................PULL & DISCH 1
SINGLE ENGINE PROCEDURE.................................APPLY
```

Alert inhibition: Electrical power on - first engine on. In landing from 400 ft to touchdown.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Rotate the ignition switch on the engine panel on the overhead panel to RELIGHT. Retard the left-hand thrust lever on the pedestal to the idle position. Move the left fuel lever on the pedestal to the SHUT position. Rotate the ignition switch on the engine panel on the overhead panel to NORM. Pull and rotate the ENG 1 Fire handle on the overhead panel.
Manifestation after correct completion of the procedure: N1 indicator of affected engine shows 0. N2 indicator shows windmilling value. EGT reducing to ambient temperature. Throttle of left-hand engine in idle position, fuel lever shut. ENG 1 fire handle is pulled. Left-hand engine AGENT 1 or 2 has amber illuminated DISCH caption. Left-hand engine indicators show values corresponding with inoperative engine. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

Aircraft type: Fokker 100
Failure case: Anti-skid failure.
Failure manifestation: Double chime. Master caution light. ANTI-SKID message on the MFDS
AOM procedure:
ANTI-SKID FAULT
APPLY BRAKES CAREFULLY
LANDING DISTANCE..CHECK

Alert inhibition: In takeoff from 80 kts to 400 ft.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Apply brakes carefully to prevent blown tires. Multiply landing distance by factor according to tables below.

LAND WEIGHT (1000 KG)	FACTOR			LAND WEIGHT (1000 KG)	FACTOR	
	FLAP 42	FLAP 25			FLAP 42	FLAP 25
28	1.61	1.78		62	1.61	1.78
31	1.72	1.92		68	1.72	1.90
34	1.82	2.04		74	1.81	2.03
37	1.93	2.17		80	1.90	2.14
40	2.03	2.27		86	2.00	2.24
43	2.11	2.37		92	2.06	2.32
46	2.17	2.44		98	2.14	2.40
48	2.22	2.48		105	2.22	2.48

Manifestation after correct completion of the procedure: No specific manifestation.

Aircraft type: Fokker 100
Failure case: Fuel leak at right-hand engine.
Failure manifestation: Excessive engine fuel flow, fuel quantity decreasing at an abnormal rate.
Possible indications: Single chime, FUEL ASYM message in amber on the MFDU. Single chime, CTR TK PUMPS message in amber on the MDFU, associated with amber LO P indication of both center tank pushbuttons on the fuel panel on the overhead panel. Single chime, COLL TK 2 LO LVL message on the MFDU. When fuel quantity in right-hand wing tank drops below 100 kg, LO +numerals (flashing) are shown on the R wing tank fuel quantity display on the fuel panel on the overhead panel.
AOM procedure:

FUEL ASYMMETRY
FUEL MANAGEMENT...CHECK

CENTER TANK PUMPS
CTR TANK PUMPS 1 AND 2......................................OFF

COLLECTOR TANK LOW LEVEL
FUEL MANAGEMENT...CHECK
AVOID EXTREME ATTITUDES

Alert inhibition: In takeoff from TO power to 1000 ft. In landing from 1000 ft to last engine off.
Incorrect or possibly misleading information: No incorrect or misleading information
Description of required action: Whichever MFDU message comes first depends on the actual fuel situation at the time the leak occurs. Most likely the fuel asymmetry message is the first to be presented, and this requires a check of fuel management. The center tank pumps message is an indication of an empty center tank and requires switching off both center tank fuel pumps by pressing both CTR TANK PUMP pushbuttons on the fuel panel on the overhead panel to OFF.
Manifestation after correct completion of the procedure: If the center tank pumps are switched off the center tank pushbuttons on the fuel panel on the overhead panel become blank. Right-hand engine will eventually flameout.

B.2. FOKKER F-27.

Aircraft type: Fokker F-27 Mk 500
Failure case: Blocked static system right-hand side.
Failure manifestation: Right-hand altimeter keeps indicating the airfield elevation. Right-hand airspeed indicator indicates too low.
AOM procedure:

```
PITOT STATIC SYSTEM
Check PITOT HEATING lights out and static selectors NORMAL.
If lights are out and selectors NORMAL:
     Select ALTERNATE SOURCE one at a time and both together.
If a static system is suspect leave selector of affected system
in ALTERNATE SOURCE.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Right-hand altimeter and right-hand airspeed present incorrect information until alternate source is selected.
Description of required action: The flight crew verifies that the pitot light is off and that the source select switches are in the normal position. These switches are located left and right on the main instrument panel. The flight crew then switches the right-hand source select switch to ALTERNATE SOURCE and cross compares the airspeed and altitude indications left and right. The right source select switch is switched back to NORMAL and the left source select switch is switch to alternate source. Again, the crew cross compares left and right airspeed and altitude indications. Finally, both source select switches are switched to ALTENRATE SOURCE and left and right altitude and airspeed indications are cross compared. From this the crew decides which system is at fault. The source select switch of the faulty system is switched to ALTERNATE SOURCE, the source select switch of the correct system is switched to NORMAL.
Manifestation after completion of the procedure: The right-hand source select switch is selected to ALTERNATE SOURCE.

Aircraft type: Fokker F-27 Mk 500
Failure case: Failure of left-hand vertical gyro.
Failure manifestation: The left-hand ADI shows a red GYRO flag and a COMPUTER flag. Attitude indication on left ADI differs from right ADI and standby horizon.
AOM procedure:

FLAG ON LH ADI

```
For attitude display use standby horizon and RH ADI
FLIGHT DIRECTOR...............................................OFF
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: LH ADI will continue to indicate incorrect attitude.
Description of required action: The flight crew must refer to RH ADI and standby horizon to obtain correct attitude information. The flight director must be switched OFF by rotating the MODE SELECTOR rotary knob on the glareshield to the OFF position.
Manifestation after completion of the procedure: The LH ADI shows red GYRO flag. The COMPUTER flag on the left ADI and the V-bar on both ADIs have disappeared. The autoflight MODE SELECTOR switch on the glareshield is in the OFF position.

Aircraft type: Fokker F-27 Mk 500
Failure case: Leak in pneumatic brake pressure bottle.
Failure manifestation: Pneumatic BRAKE pressure indicator on the center main instrument panel will indicate low brake pressure.
AOM Procedure:

```
PNEUMATIC SYSTEM LEAKAGE
Isolating valve..............................................OUT
Before gear down:
Isolating valve...............................................IN
After gear down and locked:
Isolating valve..............................................OUT
Before touch down:
Isolating .....................................................IN

Landing gear problems can be expected if the following
pressures are low:
Main bottle:
     Pressure.......................................BELOW 200 psi
     Refer to Landing Gear Fails to Extend procedure
     Pressure......................................BELOW 1000 psi
     Refer to Nosewheel Steering Failure procedure
Brake bottle:
     Pressure......................................BELOW 1500 psi
     Refer to Brake Bottle Pressure Low procedure
Alternate Bottle:
     Isolating Valve..........................................IN

Brake pressure low:
Be prepared to use alternate brake when brake bottle pressure
is reaching 1000 psi
Safety Wire...............................................REMOVE
If braking is required:
     Alternate brake.................MOMENTARY ON / BACK TO HOLD
If deceleration is not sufficient repeat the procedure
To release alternate brake pressure:
     Alternate Brake.........................................OFF
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information
Description of required action: The isolation valve lever must pulled OUT to close the isolation valves. This lever is located on the pneumatic panel at the back of the cockpit, directly behind the captain's seat. The valve lever is guarded by a lock that must be moved aft to be able to operate the lever. The isolation valve lever must be pushed in to allow operating of the landing gear and also before touchdown. During landing the alternate brake pressure must be used by breaking wire that locks the ALTERNATE WHEEL BRAKES rotary knob on the left-hand side panel. When braking is required, to ALTERNATE WHEEL BRAKES rotary knob must be momentary rotated to the ON position, and than back to HOLD.
Manifestation after completion of the procedure: No specific indication.

Aircraft type: Fokker F-27 Mk 500
Failure case: Failure of left main gear microswitch, aircraft remains in ground mode.
Failure manifestation: Landing gear lever will not move up.
AOM procedure:

```
GEAR HANDLE WILL NOT MOVE UP
Trigger on gear handle......................................PULL
Turn knob (either direction)................................60°
Gear handle...................................................UP
     Locking lever remains in down position
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The trigger on the landing gear handle must be pulled and the knob turned to allow split operation of the gear handle. The upper part must be moved to the UP position.
Manifestation after completion of the procedure: The landing gear retracts and normal indications will show the correct operation of the gear. Upper part of landing gear lever is in the UP position, lower part remains in DOWN position.

Aircraft type: Fokker F-27 Mk500
Failure case: Short circuit inverter 1 resulting in electrical smoke.
Failure manifestation: Electrical smoke.
AOM procedure:

ELECTRICAL SMOKE

Main Oxygen Bottle..OPEN
Oxygen Masks and Smoke Goggles..............................ON
Audio Selector Panel..SET
- o BOOM/MASK Microphone Selector.......................MASK
- o Interphone..ON

Essential Power Switch......................................ON
DC Power Selector...OFF
Generators..OFF
Alternators...OFF
HP Cocks..LOCK OUT
If smoke penetrates mask:
- o Select Oxygen Regulator.......................EMERGENCY

Pause - Observe Smoke

If smoke continues:
- o Assume failure essential system
- o Land at nearest airport
- o Restore Power:
  - ▪ Generators......................................ON
  - ▪ Alternators.....................................ON
  - ▪ Essential Power Switch.........................OFF
- o Isolate affected systems by pulling CB's, time permitting.

If smoke decreases:
Only essential power available
Consider restoration of electrical power as per procedure[2].

Alert inhibition: Not applicable.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.

[2] Corrective actions for power restoration are described in a two-page procedure that is not reproduced here.

Description of required action: After donning the oxygen masks and ensuring proper communications, the crew switches the ESS PWR switch to ON to energize the Essential DC and AC buses from the battery bus. The ESS PWR switch is a guarded switch located on the overhead panel. The generators and alternators are switched off by moving both GENERATOR and both ALTERNATOR toggles switches to the OFF positions. These switches are located on the overhead panel. The high pressure fuel cocks are set in the LOCK out position by pushing the HP Cock levers, located on the pedestal, fully forward. After these actions have been completed the crew monitors the conditions. If smoke continues the crew must land as soon as possible and restore power by switching the alternators and generators back on, and switching off the essential power. Affected systems may be isolated by pulling circuit breakers. There are five circuit breaker panels, the main CB panel is located at the aft cockpit wall, behind the co-pilot position.

If smoke reduces following the switch to essential power, the electrical power is gradually restored by stepwise activation of the electrical systems according to a logical scheme. This is a lengthy (two page) procedure that has not been reproduced in this report.
Manifestation after completion of the procedure: When the ESS PWR is switched ON, the ESS DC 1 and ESS DC 2 lights illuminate white on the overhead panel. When the generators are switched OFF, the two amber GENERATOR INOPERATIVE lights and the red GENERATOR BOTH INOPERATIVE light illuminate on the overhead panel. When the alternators are switched OFF, the two ALTERNATOR INOP lights illuminate red on the overhead panel. Volt and Ampere meters indicate electrical loads and voltages of the respective electrical buses. All Volt and Ampere meters are located on the overhead panel. Depending on which buses are unpowered and which CBs may have been pulled, some systems may not be operating.

Aircraft type: Fokker F-27 Mk500
Failure case: Main DC bus short circuit.
Failure manifestation: The right-hand MAIN DC bus light (white) on the overhead panel turns off. The red INVERTER 2 INOP light illuminates on the overhead panel. Various systems and indictors will show abnormal indications. The DC Volt meter on the overhead panel will indicate zero if DC Volt meter selector is set to the MAIN BUS position.
AOM procedure:

```
RH MAIN DC BUS LIGHT OUT
Main Bus Voltage............................................CHECK
If no- or low voltage
     Load shedding.........................................MANUAL

If light remains out:
     No power to:
     o  Main DC Bus
     o  Service Bus 2
     o  Secondary AC Bus
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Both torque indicators and both fuel flow indicators will show a zero value due to absence of electrical power.
Description of required action: The crew checks the voltage of the main DC bus by rotating the DC Volt meter selector knob to the MAIN DC position and checking the DC volt meter. Selector knob and volt meter are located on the overhead panel. The guarded LOAD SHEDDING toggle switch on the overhead panel is set to MANUAL.
Manifestation after completion of the procedure: The right-hand MAIN DC bus light (white) on the overhead panel is off. The red INVERTER 2 INOP light illuminates on the overhead panel. Various systems and indictors will show abnormal indications. DC Volt meter on the overhead panel indicates zero voltage.

Aircraft type: Fokker F-27 Mk500
Failure case: Leak in left-hand engine oil system.
Failure manifestation: The Master warning light on main instrument panel illuminates red on the main_instrument panel. The ENG 1 OIL PRESS light illuminates red on the main instrument panel. The Left-hand engine oil pressure indicator on the main instrument panel indicates a low value.
AOM procedure:

```
ENGINE OIL PRESSURE LIGHT ON
Oil pressure................................................CHECK
If below limit:
Carry out Manual Feathering procedure

MANUAL FEATHERING
Synchronizer..................................................OFF
HP Cock.....................................................FEATHER
Feather Button.............................PUSH UNTIL IT STAYS IN
Propeller.................................................FEATHERED
Carry out the After Feathering checklist

AFTER FEATHERING
Feather Button Light..........................................OFF
Power Lever.................................................CLOSE
Alternator....................................................OFF
Power Unit De-icing...........................................OFF
Generator.....................................................OFF
Booster Pumps Relevant Engine.................................OFF
Flap Inhibit Switch...........................................OFF
Generator Load..............................................MONITOR
Fuel Distribution...........................................MONITOR
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The synchronizer is switched off by operating the guarded Synchronizer switch on the pedestal. The left-hand HP cock on the pedestal is retarded fully to the FEATHER position. The left FEATHER button is pushed in until it stays in. A red light in the button indicated that the feathering pump is energized. The crew checks that the light goes out. The left power lever is retarded fully. The left-hand alternator, left-hand de-icing power unit, and left-hand generator are switched off by selecting the associated switches on the overhead panel to the OFF position. The booster pumps of the left-hand engine are switched off by switching the two booster pump switches for the left engine on the overhead panel to OFF. The guarded flap warning switch at the bottom of the main instrument panel is switched OFF to prevent nuisance GPWS warnings. The crew continues monitoring correct generator loads and fuel distribution.
Manifestation after completion of the procedure: Engine oil pressure warning light goes out when propeller is feathered. All indications (pressures, RPM, torque, fuel flow, electrical power, etc.) of a shut-down left engine.

Aircraft type: Fokker F-27 Mk 500
Failure case: Electrical fault in the flight fine lock circuit.
Failure manifestation: Flight fine unsafe light illuminates amber on the propellers panel on the central main instrument panel.
AOM procedure:

```
FLIGHT FINE UNSAFE LIGHT ON
Do not move power levers before flight fine isolate switch is in
isolate.
Synchronizer...............................................OFF
Flight Fine Isolate Switch.................................OFF
After touchdown:
Flight Fine Isolate Switch..............................NORMAL
Ground Fine Pitch.......................................SELECT
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The synchronizer is switched off by operating the guarded synchronizer switch on the pedestal. The flight fine isolate switch on the propellers panel on the central main instrument panel is switched off. This is a guarded switch. After touchdown, the switch has to be reset to normal before ground fine pitch is selected.
Manifestation after completion of the procedure:
Propellers are not synchronized. The flight fine unsafe light remains on (amber) as long as the flight fine isolate switch is switched off.

B.3 FOKKER 50.

Aircraft type: Fokker 50
Failure case: Attitude and Heading Reference System (AHRS) 1 failure.
Failure manifestation: Amber master caution light. Double chime. COMPARE ATT light illuminates amber on the central annunciator panel. Disagreement between LH and RH PFD. PIT (pitch disagreement), ROL (roll disagreement) or ATT (pitch and roll disagreement) appears in amber on the top right corner of both PFDs. Disagreement between LH and RH PFD.
AOM procedure:

```
COMPARE ATTITUDE
Compare LH PFD and RH PFD with stby horizon
For the incorrect PFD:
SG.....................................................ALTN
```

Alert inhibition: Master caution light and CAP light are inhibited in takeoff from 80 kts until 40 sec after liftoff.
Incorrect or possibly misleading information: The left PFD will show an incorrect attitude until the left symbol generator is switched to ALTERNATE.
Description of required action: The flight crew must compare both primary attitude indications with the standby horizon or the natural horizon to determine which of the two primary systems is at fault. The faulty system's symbol generator must be switched to alternate by pressing the left SG pushbutton on the AVIONICS panel on the overhead panel to ALTN.
Manifestation after completion of the procedure: The left SG pushbutton on the avionics panel on the overhead panel has an illuminated white ALTN caption. SG 2 appears in amber on both PFDs to indicate that one symbol generator is used for all display units.

Aircraft type: Fokker 50
Failure case: DC bus 1 failure.
Failure manifestation: Double chime. Amber Master caution light on the glareshield. Amber BUS FAULT light on the electric panel on the overhead panel. Secondary manifestations because systems on DC bus 1 are inoperative. Loss of services includes ATC transponder, DME, Weather radar, FD #1, AP#1, Fuel X-feed, Flight deck temperature control, engine anti-icing #1, Airframe de-icing, vane and shaker.
AOM procedure:

```
BUS FAULT
AFFECTED BUS...........................................DETERMINE
BUS EQUIPMENT LIST.........................................CHECK
```

Alert inhibition: Master caution light is inhibited in takeoff from 80 kts until 40 sec after liftoff.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The affected bus must be determined by rotation of the display selector on the electric panel on the overhead panel to the various bus positions. The affected bus voltage will read zero. The Bus equipment list can be found in the AOM or QRH and shows which systems are inoperative in case of a DC bus 1 failure.
Manifestation after completion of the procedure: Display rotary selector on the electric panel on the overhead panel set to DC. Left-hand electric display on the overhead panel shows zero voltage. Secondary manifestations because systems on DC bus 1 are inoperative.

Aircraft type: Fokker 50
Failure case: Short circuit in AC system resulting in electrical smoke.
Failure manifestation: Visible smoke, odor.
AOM procedure:

ELECTRICAL SMOKE

```
OXY MASK/GOGGLES..........................................AS REQD
CREW COMMUNICATION......................................ESTABLISH
RECIRC FANS.............................................BOTH OFF
ECONOMY.......................................................OFF
GEN 1 and 2...................................................OFF
AVOID ICING CONDITIONS
LAND AS SOON AS PRACTICABLE
If unable to land within 30 min:
     AUTO AC X-FEED...........................................OFF
     GEN 1.....................................................ON
     If smoke re-appears:
          GEN 2................................................ON
          GEN 1...............................................OFF
          SMOKE REMOVAL PROC (IF REQD).......................APPLY
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: After putting on the oxygen masks and the smoke goggles, the flight crew should establish crew communication by selecting the speaker switch to OXY on both audio panels. Recirculation fans are both switched off by pressing both RECIRC pushbuttons on the air conditioning panel on the overhead panel. Economy is switched off by pressing the ECONOMY pushbutton on the air conditioning panel on the overhead panel. Generator 1 and 2 are switched OFF by pressing both pushbuttons on the electric panel on the overhead panel. The aircraft then is on battery power only. If it is not possible to land within 30 minutes the auto AC X-FEED pushbutton on the electric panel on the overhead panel must be switched OFF, and generator 1 must be switched on again by depressing GEN 1 pushbutton. If smoke reappears, generator 2 must be switched on and generator 1 switched off.
Manifestation after completion of the procedure: The RECIRC pushbuttons on the Air conditioning panel on the overhead panel have white illuminated OFF caption. The ECONOMY pushbutton on the air conditioning panel on the overhead panel is blank. Both GEN pushbuttons on the electric panel on the overhead panel have illuminated white OFF caption. If on battery power (both generators off) only the left-hand PFD is available.

Aircraft type: Fokker 50
Failure case: Leak in hydraulic system.
Failure manifestation: Hydraulic quantity indicator on the hydraulic panel on the overhead panel shows decreasing values, if display selector is set to QTY. Double chime. Master caution light illuminates amber on the glareshield. Low quantity light illuminates amber on the hydraulic panel on the overhead panel. Depending on the rate of fluid loss the hydraulic pressure indication will display a decreasing system pressure.
AOM procedure:

```
TANK LOW QUANTITY
BOTH ENG PUMPS................................................OFF
     During approach:
     ALTERNATE FLAP.......................................OPERATE
     ALTERNATE LG SELECTOR...................................DOWN
     NORMAL LG SELECTOR......................................DOWN
     After landing:
     NOSE WHEEL STEERING IS INOPERATIVE
     NORMAL BRAKES..........................................APPLY
     If normal brakes pressure falls below 1000 psi:
       ALTERNATE BRAKE......................................APPLY
       SKID CONTROL NOT AVAILABLE
     LEAVE NORMAL AND ALTERNATE LANDING GEAR SELECTOR DOWN
```

Alert inhibition: In takeoff from 80 kts until 40 sec after liftoff.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The engine driven pumps are switched off by pressing the L and R ENG PUMP pushbuttons on the hydraulic panel on the overhead panel. During the approach, flaps and landing gear must be operated using the alternate system. Alternate flap is operated by the alternate flap control switch adjacent to the flap selector. The alternate gear selector is located at the RH aft side of the pedestal and has to be pulled upward to select alternate down. During landing the alternate brakes should be operated if brake pressure falls below 1000 psi. Normal brake pressure is indicated on the center main instrument panel. The alternate brake system is controlled by two handles at the LH side panel.
Manifestation after completion of the procedure: Both ENG PUMP switches on the hydraulic panel on the overhead panel have illuminated white OFF caption. Low quantity light illuminates amber on the hydraulic panel on the overhead panel.

Aircraft type: Fokker 50
Failure case: Ground and flight sensors remain in ground.
Failure manifestation: Gear lever locked down. AP engagement is not possible because automatic yaw damper engagement is inhibited when the aircraft is on the ground.
AOM procedure:

LANDING GEAR SELECTOR LOCKED IN DOWN POSITION

```
LOCK OVRD.......................................PUSH AND HOLD
LANDING GEAR SELECTOR..................................UP
LOCK OVRD.............................................RELEASE
```

Alert inhibition: Not applicable.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Depress and hold the selector lock override button, located on the landing gear panel on the center forward panel, while moving the landing gear selector to UP, and release the selector lock override button. The flight crew may engage the yaw damper manually by pushing the YD ENGAGE button on the autopilot control panel on the pedestal, thereafter the AP can also be engaged.
Manifestation after correct completion of the procedure: Landing gear selector up.

Aircraft type: Fokker 50
Failure case: Engine 1 oil leak.
Failure manifestation: Red master warning light. Repetitive triple chime, red L ENG OIL PR warning light illuminates on the central annunciator panel on the center main instrument panel. LH engine oil pressure indication indicator on the center main instrument panel indicates low pressure. Left fuel level illuminates white.
AOM procedure:

```
ENGINE OIL PRESSURE LOW
OIL PRESSURE INDICATOR.....................................CHECK
If pressure is within the green band:
     Continue engine operation
     OIL PRESSURE.........................................MONITOR
If pressure is below 40 psi:
     POWER LEVER........................................FLT IDLE
     FUEL LEVER.............................................SHUT
     SINGLE ENGINE PROCUDURE...............................APPLY
```

Alert inhibition: Alert is not inhibited.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The flight crew must check the oil pressure indicator on the main instrument panel. If the indication is within the green band (between 55 and 65 psi), no immediate action is required. If the pressure has dropped below 40 psi, the engine must be shut down by retarding the left power lever to idle and retarding the left fuel lever to the SHUT position.
Manifestation after completion of procedure: Left power lever retarded to idle, left fuel valve retarded to shut. Indications corresponding to left engine inoperative.

Aircraft type: Fokker 50
Failure case: Propeller 1 electronic control fault.
Failure manifestation: Double chime. Amber master caution light illuminates on the glareshield. L PROP EC light illuminates amber on the central annunciator panel. The left PROP EC pushbutton on the propeller panel on the overhead panel has an amber illuminated FAULT caption. Propeller speed of the left propeller increases to 104 percent and propeller synchronization and synchrophasing are not functioning.
AOM procedure:

```
PROPELLER ELECTRONIC CONTROL FAULT
PROP EC...............................................OFF THEN ON
If reset is unsuccessful:
     PROP EC..............................................OFF
     NP will increase to 104 per cent
     In case of go-around set torque 6 per cent below bug.
     Restrict speed to max 220 kt TAS
     If NP is not stable:
          SHUTDOWN PROCEDURE................................APPLY
```

Alert inhibition: In takeoff from 80 kts until 40 sec after liftoff.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The left PROP EC pushbutton on the propeller panel on the overhead panel is pushed to OFF and then to ON again. If this has no effect it is pushed to OFF. This is a guarded switch. Speed must be kept below 220 kts TAS.
Manifestation after completion of the procedure: The left PROP EC pushbutton on the propeller panel on the overhead panel has white illuminated OFF caption. Left propeller speed increased to 104 percent, propeller synchronization and synchrophasing are not functioning.

B.4 FOKKER F-28.

Aircraft type: Fokker F-28
Failure case: Blocked static port, right-hand side.
Failure manifestation: Left and right airspeed, altitude and vertical speed indications differ.
AOM procedure:
DIFFERENCE BETWEEN AIRSPEED INDICATORS AND ALTIMETERS
STATIC PRESSURE SELECTOR.........................ALTERNATE SOURCE
Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Incorrect airspeed on the right-hand airspeed indicator. Incorrect altitude on the right-hand altimeter. Incorrect vertical speed on the right-hand vertical speed indicator.
Description of required action: The captain and first officer should each select the alternative static port by switching the static source select switches (a guarded toggle switch) to ALTERNE SOURCE. Both switches are located on the main instrument panel.
Manifestation after completion of the procedure: LH and RH static source selector switches are in the ALTERNATE SOURCE position. No difference between LH and RH altitude, speed and vertical speed indications.

Aircraft type: Fokker F-28
Failure case: Hydraulic system 1 (utility system) leak.
Failure manifestation: System 1 hydraulic quantity indicator shows decreasing quantity (dropping below normal green range). Indicator is located on the secondary instrument panel.
AOM procedure:

DECREASING QUANTITY

PUMP SWITCHES.......................................BOTH OFF LOAD

If utility system affected:

Reset pump switches to NORMAL prior to landing or at Captain's discretion use alternate systems.

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect information displayed.
Description of required action: Both pump switches of UTILITY System 1 (toggle switches) must be switched from NORMAL to OFF LOAD. Switches are located on secondary instrument panel.
Manifestation after correct completion of the procedure: Utility1 pump switches are in OFF LOAD position. Hydraulic system 1 quantity will continue to drop. Utility systems (drives speed brakes, wheel brakes, alternate brakes, flaps and slats, landing gear, nose wheel steering and lift dumpers) are inoperative.

Aircraft type: Fokker F-28
Failure case: Ground and flight logic switch remains in ground mode after liftoff.
Failure manifestation: Landing gear selector blocked in down position.
AOM procedure:

HANDLE OBSTRUCTED IN DOWN POSITION

AIRFOIL ANTI-ICING SYSTEM..........................MOMENTARILY ON

- If both airfoil anti-ice systems operate normally:
  L/G OVERRIDE BUTTON................................PUSH & HOLD
  L/G HANDLE..UP
- If one or both airfoil anti-ice is inoperative:
  L/G HANDLE..LEAVE DOWN
  LAND AS SOON AS POSSIBLE

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Switch both main airfoil anti-ice toggle switches, located on the airfoil anti-ice panel on the overhead panel, to the ON position. Operation of the anti-ice system is indicated by the airfoil anti-icing shut-off valve indicators which will take an ‘in-line’ position, indication that the shut-off valve is not closed. If the anti-ice system is inoperative, the indicator(s) will remain in the ‘off line’ position. Anti-ice shut-off valve indicators are located on the airfoil anti-ice panel on the overhead panel. When operation of airfoil anti-ice is observed, both airfoil anti ice main switches should be switched to the OFF/RESET position.
Note: If the ground-flight switch remains in ground mode, one of the anti-ice systems will remain inoperative.
Manifestation of correct completion of procedure: Landing gear selector in down position.

Aircraft type: Fokker F-28
Failure case: Non-annunciated AC bus 2 failure resulting in electrical smoke in the cockpit.
Failure manifestation: Electrical smoke.
AOM procedure:

ELECTRICAL SMOKE OR FIRE

```
OXYGEN MASK...........................................ON 100%
SMOKE GOGGLES (if required).................................ON
CREW COMMUNICATIONS..................................ESTABLISH
EMERGENCY POWER SWITCH...................................OPERATE
```

- IF SMOKE CONTINUES

```
ALL GENERATOR SWITCHES ....................................OFF
LAND AT NEAREST SUITABLE AIRPORT
```

- IF SMOKE STOPS OR DECREASES

```
Restore power slowly and check for recurrence of smoke
and/or excessive electrical loads
BUS TRANSFER ISOLATE SWITCHES .........................OPERATE
TRU SWITCHES ..............................................OFF
GEN 2 SWITCH ..............................................OFF
EMERGENCY POWER SWITCH ............................GUARD CLOSED
      o IF SMOKE RECURS
        GEN 1 SWITCH.......................................OFF
        GEN 2 SWITCH.......................................OFF
        TRU 2 SWITCH........................................ON
      o IF SMOKE DOES NOT RECUR
        TRU 1 SWITCH........................................ON
          ▪ IF SMOKE RECURS
            TRU 1 SWITCH...................................OFF
            GEN 2 SWITCH ...................................ON
            BUS TRANSFER ISOLATE SWITCHES........GUARDS CLOSED
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possible misleading information.
Description of required action: The procedure initially removes electrical power of all nonessential services and then subsequently removes and restores power from and to each electrical system.

When the oxygen masks and smoke goggles have been put on, and crew communication has been established, the crew must operate the EMERGENCY POWER switch, a guarded switch located on the electrical power panel on the overhead panel. The crew then has to pause for approximately 3 to 4 minutes to observe whether the smoke reduces. In this case, the smoke is caused by an AC bus 2 short circuit, so the smoke will reduce. The crew then must operate the BUS 1 and BUS 2 TRANSFER ISOLATE switches (these switches are guarded), select the TRU 1 and TRU 2 switches (toggle switches) to the OFF position, select the GEN 2 switch (toggle switch) to the OFF/RESET position, and close the guard on the EMERGENCY POWER switch. All switches are located on the electrical power panel on the overhead panel. Again, a pause of 3 to 4 minutes to observe reduction of smoke. For this failure case, smoke does not recur, and the crew has to select TRU switch 1 to the ON position. Again, a pause of 3 to 4 minutes to observe smoke. In this failure case, smoke does not recur and the procedure is completed.

Manifestation after completion of the procedure: AC bus 2 is unpowered, all other busses are powered. The GEN 2 switch is in the OFF/RESET position. The GEN 2 INOPERATIVE light illuminates amber. The AC BUS 2 light (white) is not illuminated. The TRU 2 switch is in the OFF position. The TRU 2 magnetic indicator is in the ‘of line’ position. All indications are local on the electrical power panel on the overhead panel.

Aircraft type: Fokker F-28
Failure case: Transformer Rectifier Unit (TRU) no. 2 overheat failure.
Failure manifestation: Amber TRU 2 OVERH light illuminated on the Electrical power panel on the overhead panel.
AOM procedure:
TRU OVERH LIGHT ON
TRU switch...OFF
Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Switch the TRU 2 toggle switch on the electrical panel on the overhead panel to OFF.
Manifestation after correct completion of the procedure: TRU bus 2 magnetic indicator on the electrical panel on the overhead panel is OFF LINE.

Aircraft type: Fokker F-28
Failure case: Engine 1 low pressure compressor bearing collapse.
Failure manifestation: Rapid decrease of N1 to 0. TGT increases rapidly. Loud bang, sudden high-frequency vibration, decreasing as N1 slows down. Engine vibration indicator shows high amplitude. Engine flameout approximately 30 seconds after the seizure. N2 goes to windmilling value, TGT slowly decreases to ambient temperature. THRUST indication affected engine reduces to 0%. TGT, N1, N2, Vibration, and THRUST indicators are located on the central main instrument panel. Abnormal electric and hydraulic indications due to the inoperative engine. No 1 CONSTANT SPEED DRIVE light illuminates red on the Annunciator Panel on the Side Panels.
AOM procedure:

```
ENGINE FIRE/DAMAGE
Identify engine
H.P.  FUEL LEVER...........................................SHUT
ENGINE FIRE Control Guard..................................LIFT
       o Lifting the guard will close both fuel and hydraulic
         valves.
Extinguisher Switch......................................SHOT 1
Wait 45 minimum, if fire still persists:
Airspeed.................................................REDUCE
Extinguisher Switch......................................SHOT 2
When time permits:
THROTTLE Lever.............................................IDLE
CROSS FEED Switch............................................ON
BLEED AIR MAIN Switch.................................OFF/RESET
APU.......................................................START
CSD DISCONNECT Guard/Switch........................LIFT/OPERATE
       o Both pilots confirm which CSD is affected.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Move the H.P. Fuel Valve lever of the failed engine to the close position. H.P. fuel valve lever is located on the pedestal. Lift the Engine Fire Control Guard of the failed engine on the glareshield. The extinguisher toggle switch now becomes visible. Move the extinguisher toggle switch to the Shot 1 position. Wait 45 seconds. Move the throttle lever of the failed engine (located on the pedestal) to idle. Move CROSS FEED switch (toggle switch on the pedestal) to ON position. Move BLEED AIR MAIN toggle switch on the Bleed Air Supply Panel on the overhead panel to the OFF/RESET position. Switch APU MAIN toggle switch to ON position. Switch is located on the APU Control Panel on the overhead panel. Press the APU START button. Button is located on the APU Control Panel on the overhead panel. When APU RPM and TGT have stabilized switch GEN 3 toggle switch to ON. Switch is located on the APU Control Panel on the overhead panel. Lift the guard and operate the CONSTANT SPEED DRIVE DISCONNECT switch of the affected engine to the up position. Switch is located on the overhead panel.

Manifestation after correct completion of the procedure: N1 indicator of affected engine indicates 0. N2 indicator shows windmilling value. TGT reducing to ambient temperature. THRUST indication affected engine 0%. HP fuel lever of affected engine is in the SHUT position. Fuel flow affected engine indicates 0. ENGINE FIRE Control Guard of the affected engine is lifted, extinguisher switch is in the SHOT 1 position. Fuel shut-off valve indicator indicates SHUT. Indicator is located on the glareshield panel. CROSS FEED switch is in the ON position. CROSS FEED light illuminates blue on the pedestal. BLEED AIR MAIN toggle switch is on the OFF/RESET position. APU light illuminates white on the main instrument panel. APU RPM, TGT and AC load indicator show normal APU operation. Additionally abnormal electric and hydraulic indications due to one engine inoperative.

Aircraft type: Fokker F-28
Failure case: Vertical gyro no 1 failure.
Failure manifestation: Red GYRO flag appears in front of the left-hand ADI. LH and RH ADI show different attitudes. ATT light illuminates on the Comparator Warning Monitor System on the main instrument panel. Red COMPUTER and SPEED flags appear in front of both ADIs if Flight Director is ON.
AOM procedure:
ATTITUDE DISPLAY ADI 1 UNRELIABLE
Use standby horizon and ADI 2
Select FD...OFF
Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Incorrect attitude on left-hand ADI.
Description of required action: Set the Flight Director mode selector switch to OFF. Switch is located on the glareshield panel.
Manifestation after correct completion of the procedure: Red GYRO flag appears in front of the left-hand ADI. LH and RH ADI show different attitudes. ATT light illuminates on the Comparator Warning Monitor System on the main instrument panel. FD selector switch in OFF position.

Aircraft type: Fokker F-28
Failure case: Fuel leak at the right-hand engine.
Failure manifestation: Right-hand fuel quantity decreasing at an abnormal rate, indicator is located on the central main instrument panel. Excessive right-hand engine fuel flow, fuel flow indicator is located on the central main instrument panel. When right-hand tanks are nearly empty: Right-hand collector tank low-level indicator on the pedestal shows barberpole. Amber FUEL PRESS light illuminates on the central main instrument panel.
AOM procedure:

COLL TANK INDICATOR BARBERPOLE

```
Check BOOSTER PUMP switches...................................ON
Check PUMP lights............................................OUT
Collector tank quantity..................................MONITOR
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Check that the right-hand FWD and AFT booster switches are ON. The booster switches are toggle switches located on the pedestal. Check that the right-hand FWD and AFT booster pump lights on the pedestal are out. Monitor the fuel quantity in the right-hand collector tank by rotating the right-hand fuel quantity selector knob on the central main instrument panel to COLL and observe Fuel quantity on the indicator.
Manifestation after completion of the procedure: Right-hand collector tank low-level indicator on the pedestal shows barberpole. Amber FUEL PRESS light illuminates on the central main instrument panel. Right-hand fuel quantity indicator indicates empty fuel tank. Right-hand engine will eventually flameout.

B.5 BOEING 737-300/400/500.

Aircraft type: Boeing 737-300/400/500
Failure case: Blocked static port, right-hand system.
Failure manifestation: Left and right Mach/airspeed indications differ. Left and right altitude indications differ.
AOM procedure:

```
AIRSPEED UNRELIABLE
AIRPLANE ATTITUDE/THRUST...................................ADJUST
PITOT STATIC HEAT.......................................CHECK ON
MACH/AIRSPEED INDICATORS...............................CROSSCHECK
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Incorrect airspeed on the right-hand Mach/airspeed indicator. Incorrect altitude on the right-hand altimeter.
Description of required action: Unreliable airspeed is recognized by airplane pitch attitude inconsistent with existing phase of flight attitude, thrust and weight or by noise and/or low frequency buffeting. ON position of pitot static heat toggle switches A and B must be checked. Switches are located on the Pitot Static Heat Panel on the Forward Overhead Panel. Crosscheck ground speed and winds by the IRS and FMC to determine airspeed accuracy if indicated airspeed is questionable.
Failure manifestation after correct completion of the procedure: Left and right Mach/airspeed indications differ. Left and right altitude indications differ.

Aircraft type: Boeing 737-300/400/500 (EFIS equipped)
Failure case: IRS 1 failure.
Failure manifestation: Amber master caution light. IRS illuminated amber on the left-hand light shield. Amber FAULT light on the left side of the IRS Mode Selector Unit on the Aft Overhead Panel. Amber PITCH and ROLL annunciation on both EADIs if there is a difference of more than 3 degrees between the Captain's and F/O's pitch or roll displays.
AOM procedure:

```
IRS FAULT
IRS MODE SELECTOR (affected IRS)..............................ATT
Maintain straight and level, constant airspeed flight until
displays recover (approximately 30 seconds).
If the FAULT light extinguishes:
     MAGNETIC HEADING.......................................ENTER
          Enter updated heading periodically on the POS INIT
          page or on the overhead IRS display unit by selecting
          HDG/STS.
     Do not use autopilot approach mode
If the FAULT light remains illuminated:
     IRS TRANSFER SWITCH...................BOTH ON L or BOTH ON R
     Note:  Do not engage either autopilot.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: Incorrect attitude is displayed on the LH EFIS until IRS transfer switch is positioned to BOTH ON R.
Description of required action: The IRS MODE SELECTOR SWITCH of the left-hand IRS must be positioned to ATT. This switch is located on the IRS Mode Selector Unit on the aft overhead panel. The aircraft has to be kept on a straight and level flight witch constant airspeed for at least 30 seconds. If the IRS fault light remains the IRS TRANSFER toggle switch has to be positioned to BOTH ON L. This switch is located on the Forward Overhead Panel.
Failure manifestation after correct completion of the procedure: Instrument Transfer Switch Light illuminates amber on the main instrument panel. IRS illuminated amber on the left-hand light shield. Amber FAULT light on the left side of the IRS Mode Selector Unit on the Aft Overhead Panel.

Aircraft type: Boeing 737-300/400/500
Failure case: Non-annunciated AC bus 2 failure resulting in electrical smoke in the cockpit.
Failure manifestation: Electrical smoke.
AOM procedure:

ELECTRICAL SMOKE

```
OXYGEN MASKS & REGULATORS................................ON, 100%
SMOKE GOGGLES...................................................ON
CREW COMMUNICATIONS.....................................ESTABLISH
If smoke source can be determined
     ELECTRICAL POWER......................................REMOVE
If smoke source cannot be determined
     BUS TRANSFER SWITCH......................................OFF
     GALLEY POWER SWITCH......................................OFF
     Land at the nearest suitable airport.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: First the oxygen masks and smoke goggles must be been put on, and crew communications must be established. If the smoke source is readily identifiable from a specific bus or component, the electrical power should be removed from it. If the smoke source is not clear, the BUS TRANSFER switch should be set on the OFF position. The bus transfer switch is a guarded switch located on the Electrical Panel on the Forward Overhead panel. The galley power toggle switch should be set in the OFF position. The galley power switch is located on the Electrical Panel on the Forward Overhead panel.
Manifestation after correct completion of the procedures: Assuming that the source of the smoke is not clear, both amber TRANSFER OFF lights will be illuminated. Lights are located on the Electrical Panel on the Forward Overhead Panel. Electrical smoke will continue.

Aircraft type: Boeing 737-500
Failure case: Generator drive no. 1 low oil pressure.
Failure manifestation: GENERATOR DRIVE LOW OIL PRESSURE light illuminates amber on the electrical panel on the overhead panel.
AOM procedure:

GENERATOR DRIVE LOW OIL PRESSURE

```
GENERATOR DRIVE DISCONNECT SWITCH......................DISCONNECT
APU (if available).................................START & ON BUS
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Disconnect the generator drive by operating the guarded and safetied no. 1 generator drive, disconnect switch on the electrical panel on the overhead panel. The APU is started by momentarily positioning the APU switch to the start position. The APU switch is located on the forward overhead panel. The APU GEN OFF light will illuminate blue on the electrical panel on the overhead panel when the APU is at governed speed, ready to accept a load. The left APU GEN switch on the electrical panel on the overhead panel must then be switched to ON.
Manifestation after correct completion of the procedures: APU is running and providing power to the left bus.

Aircraft type: Boeing 737-300/400/500 (EIS equipped aircraft)
Failure case: Hydraulic system A leak in tank.
Failure manifestation: The System A quantity as indicated on the center instrument panel steadily decreases to zero % and all system pressure is lost. MASTER CAUTION lights (amber) illuminated right and left on the light shield. HYD annunciator light illuminates amber on the right side light shield. FLT CONT annunciator light illuminates amber on right side light shield. System A hydraulic pump LOW PRESSURE lights illuminate amber on the Hydraulics Panel on the Forward Overhead Panel. System A LOW PRESSURE light illuminates amber on the Flight Control Panel on the Forward Overhead Panel. FEEL DIFF PRESS LIGHT illuminates amber on the Flight Control Panel on the Forward Overhead Panel.
AOM procedure:
LOSS OF SYSTEM A
SYSTEM A FLIGHT CONTROL SWITCH...........................STBY RUD
SYSTEM A HYDRAULIC PUMPS...................................OFF
Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: SYSTEM A FLT CONTROL switch on the Flight Control Panel on the Forward Overhead Panel must be set to the STBY RUD position. The ENG 1 and ELEC 2 HYD PUMPS switches for System A must be switched to the OFF position. Switches are located on the Hydraulic Panel on the Forward Overhead Panel.
Manifestation after correct completion of the procedure: The System A quantity indicator on the center instrument panel reads 0%. System A hydraulic pump LOW PRESSURE lights illuminate amber on the Hydraulics Panel on the Forward Overhead Panel. FEEL DIFF PRESS LIGHT illuminates amber on the Flight Control Panel on the Forward Overhead Panel.

Ground spoilers, inboard flight spoilers, normal nose wheel steering and alternate brakes are inoperative. Landing gear must be extended manually.

Aircraft type: Boeing 737-300/400/500 (EIS equipped)
Failure case: LP compressor bearing collapse.
Failure manifestation: Rapid decrease of N1 to 0. EGT increases rapidly. Loud bang, sudden high-frequency vibration, decreasing as N1 slows down. Engine vibration indicator shows high level. Engine flameout approximately 30 seconds after the seizure. N2 goes to windwilling value, EGT slowly decreases to ambient temperature. EGT, N1, N2 indicators are located on the Engine Instrument System Primary Panel on the Center Instrument Panel. Vibration indicator is located on the Engine Instrument System Secondary panel on the Center Instrument panel. LOW OIL PRESSURE Light and/or BUS OFF Lights and other abnormal electric and hydraulic indications due to the inoperative. Amber ELEC system annunciator on the left side Light Shield. MASTER CAUTION Light illuminates amber. LOW OIL PRESSURE Light is located on the Engine Instrument System Secondary panel on the Center Instrument panel. BUS OFF light is located on the Electrical Panel on the Forward Overhead Panel.
AOM procedure:

ENGINE FIRE, SEVERE DAMAGE OR SEPARATION

```
THRUST LEVER..............................................CLOSE
AUTOTHROTTLE (if engaged)..............................DISENGAGE
START LEVER..............................................CUTOFF
ENGINE FIRE WARNING SWITCH..................................PULL
If the Engine Fire Warning or ENG OVERHEAT Light remains
illuminated:
     ENGINE FIRE WARNING SWITCH....................ROTATE L OR R
If after 30 seconds the Engine Fire Warning or ENG OVERHEAT
Light remains illuminated:
     ENGINE FIRE WARNING SWITCH........ROTATE TO REMAINING BOTTLE
If the engine Fire Warning or ENG OVERHEAT Light remains
illuminated:
     Land at the nearest suitable airport.
ISOLATION VALVE SWITCH....................................CLOSE
APU BLEED AIR SWITCH........................................OFF
APU (if available)..................................START & ON BUS
FUEL ...................................................BALANCE
If wing anti-ice is required:
     PACK SWITCH (affected side)..............................OFF
     ISOLATION VALVE SWITCH..................................AUTO
Accomplish the ONE ENGINE INOPERATIVE LANDING Checklist when
appropriate.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Move the Thrust Lever to the CLOSE position. Disengage the autothrottle by pushing the A/P disengage switch. Move the Start Lever to the CUTOFF position. Thrust Lever and Start Lever are located on the pedestal. Pull and rotate the ENGINE FIRE WARNING Switch. This switch is located on the Aft Electronic Panel on the pedestal. Move the ISOLATION VALVE switch to the CLOSE position. This switch is located on the Bleed Air Control panel on the Forward Overhead Panel. Move the APU BLEED AIR switch to the OFF position. This switch is located on the Bleed Air Control panel on the Forward Overhead Panel. Start the APU by momentarily moving the APU switch to START. The switch

is located on the APU panel on the Forward Overhead Panel. Move the relevant APU GEN switch to the ON position. The switch is located on the Bus Electrical panel on the Forward Overhead Panel.

Manifestation after correct completion of the procedure: N1 indicator of affected engine shows indicates 0. N2 indicator shows windmilling value. EGT reducing to ambient temperature. Thrust Lever and Start Level are in the CLOSE position. Engine Fire switch of the affected engine pulled and rotated. The L or R BOTTLE DISCHARGE light on the Aft Electronic panel illuminates amber. The Isolation Valve switch is in the CLOSE position. APU indicators show APU is running. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

Aircraft type: Boeing 737-300/400/500
Failure case: Air ground sensor remains ground mode after takeoff.
Failure manifestation: Landing gear lever will not move up after takeoff. The Takeoff Configuration warning sounds after flaps have been fully retracted (intermittent warning horn).
AOM procedure:

GEAR LEVER WILL NOT MOVE UP AFTER TAKEOFF

```
LANDING GEAR LEVER..........................................DOWN
If the Takeoff Configuration Warning remains silent after the
flaps are fully retracted:
     LANDING GEAR OVERRIDE TRIGGER..........................PULL
     LANDING GEAR LEVER................................UP & OFF
If Takeoff Configuration Warning sounds when flaps are fully
retracted:
     LANDING GEAR AIR/GND RELAY AND LIGHTS C/B (P6-3)........PULL
     Land at the nearest suitable airport
     CAUTION:  DO NOT OPERATE THE SPEEDBRAKES INFLIGHT

DESCENT APPROACH
     ANTI ICE.........................................AS REQUIRED
     AIR COND & PRESS.........................................SET
     ALTIMETER AND INSTRUMENTS....................SET & X-CHECKED
     N1 & IAS BUGS............................CHECKED & SET, VREF

LANDING
     START SWITCHES............................................ON
     RECALL...............................................CHECKED
     SPEED BRAKE.....................................DOWN DETENT
     LANDING GEAR LEVER......................................DOWN
     LANDING GEAR AIR/GND RELAY AND LIGHTS C/B (P6-3).......RESET
     LANDING GEAR DOWN, 3 GREEN
     LANDING GEAR AIR/GND RELAY AND LIGHTS C/B (P6-3)........PULL
     FLAPS.....................................xxx, GREEN LIGHT
     Manually deploy the speedbrakes immediately upon touchdown.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The flaps must be retracted. If the takeoff configuration warning sounds after the flaps have been fully retracted, the LANDING GEAR AIR and GND RELAY AND LIGHTS circuit breaker must be pulled. This circuit breaker is located on panel P6-3, aft in the cockpit. During the approach this circuit breaker has to be reset to be able to check the three green landing gear lights. After this, the circuit breaker must be pulled again. The speedbrakes have to be deployed manually after touchdown.

Manifestation after correct completion of the procedure: Landing gear selector on down position. After landing with the C/B pulled, some abnormal system reactions are: the pressurization system will maintain a small positive pressure and inboard wheel brakes are inoperative at taxi speeds.

Aircraft type: Boeing 737-300/400/500
Failure case: Reverser unlocked inflight.
Failure manifestation:
The REVERSER UNLOCKED light illuminates amber on the center instrument panel. The unstowed reverser may also produce buffet, yaw, roll, and increased drag.
AOM procedure:

```
REVERSER UNLOCKED (INFLIGHT)
FORWARD THRUST LEVER (Affected engine)......................CHECK
Caution:  DO NOT ACTUATE THE REVERSE THRUST LEVER
If the forward thrust lever is unrestricted and no buffet or
yaw exists:
     Operate the engine normally.
If the forward thrust lever is restricted or buffet or yaw
exists:
     Accomplish the ENGINE FAILURE AND SHUTDOWN Checklist.
     Accomplish the ONE ENGINE INOPERATIVE LANDING Checklist.
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The flight crew must check if movement the thrust lever of the affected engine is unrestricted. Restricted movement is an indication of a reverser unlock because an interlock limits movement of the thrust lever as long as the engine is in reverse thrust.
Manifestation after correct completion of the procedure: Affected engine is shut down. Engine indicators show values corresponding with inoperative engine. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

B.6 AIRBUS A310.

Aircraft type: Airbus A310
Failure case: ADC 1 failure.
Failure manifestation: Single chime. NAV ADC, ATS and FLT CTL lights illuminated amber on the warning light display panel on the center main instrument panel. Red OFF flag covers altimeter counter of Captain's altimeter, red OFF flag appears on Captain's vertical speed indicator and the pointer returns to zero, red Mach flag appears, flashing for a few seconds, then steady, on the captain's PFD, red speed flag appears, flashing for a few seconds, then steady, on the captain's PFD. All symbols on the speed scale are removed and the scale turn red. Left ECAM displays the ADC FAULT procedure. Both ATS disarm.
AOM procedure:
ADC FAULT
ADC INST SWITCHING...................................SYS AVAILABLE
ATC..SYS AVAILABLE
ATS...RESET
Alert inhibition: In takeoff from 70 kts until liftoff, in landing from touchdown to 70 kts.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The captain must select ADC system 2 by pressing the ADC INST pushbutton on the CAPT SWITCHING panel on the left main instrument panel. The ATC transfer switch on the pedestal must be switched to 2. The autothrottle has to be reset.
Manifestation after completion of the procedure: ADC INST pushbutton on the CAPTAIN SWITCHING panel on the left main instrument panel has a white illuminated SYS 2 caption, the ADC INST pushbutton on the F/O SWITCHING panel on the left main instrument panel has a green illuminated CAPT/2 caption.

Aircraft type: Airbus A310
Failure case: AC Bus 2 fault resulting in electrical smoke.
Failure manifestation: Electrical smoke. Continuous repetitive chime. SMOKE light illuminates red on the warning light display panel on the center main instrument panel. The AVIONICS SMOKE procedure is displayed o the left ECAM display. AVIONICS SMOKE light comes on red on the ELEC PWR panel on the overhead panel.
AOM procedure:

```
AVIONICS SMOKE
SNIFFER FAN..............................................OPERATE
IF SMOKE CONFIRMED:
     OXY MASK/GOGGLES.........................................ON
     CREW COMMUNICATIONS...............................ESTABLISH
     VHF 1 / ATC 1........................................SELECT
     PILOT FLYING.............................................CM1
     APU GEN................................................OFF/R
     OVRD SUPPLY 1 AND 2.......................................ON
     VENT EXTRACT............................................OVBD
     PITCH TRIM 1 / YAW DAMPER 1 / AP-FD1...................RESET
     ND 1 (VOR/ADF1/ILS1)...............................ROSE MODE
     AVOID ICING CONDITIONS
     LAND ASAP
     LDG GEAR POSITION DET...................................SYS 1
     PACKS (if required)...................................MAN CTL
     SMOKE REMOVAL PROC (if necessary).......................APPLY
     When FUEL LO LVL lt.  on:
          IGNITION.................................CONT RELIGHT
          MAX FL.................200 (150 if JP4/JET B used)/MAE
          OUTR TK ISOL VALVES...............................OFF
          CAUTION:  avoid rapid throttle movement and negative
          load factors
     Before slats extension:
          LAND RECOVERY......................................ON
          LDG SPD INCREMENT...............................+ 10 KT
          LDG DIST..............................MULTIPLY BY 1.4
          NOTE:  Nose wheel steering and reverse are inop
     After landing:
          MAN PRESS -V/S CTL..............................ON/UP
```

Alert inhibition: 50 kts - 400 ft, 400 ft - 50 kts.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: A fan located in the duct from the avionics compartment provides olfactory confirmation of smoke via a sniffer tube. To operate the fan, the First Officer must press and hold the sniffer fan pushbutton. The button is located on the right-hand side panel. When the smoke is confirmed as avionics smoke the oxygen masks and smoke goggles must be been put on, and crew communications must be established. VHF 1/ATC 1 must be selected by depressing the VHF 1 pushbutton on the pedestal. The pilot in the left-hand seat takes the role of pilot flying. The APU GEN pushbutton must be released-out. The pushbutton is located on the ELEC PWR panel on the overhead panel. Both OVRD SUPPLY pushbutton

switches must be depressed. The switches are guarded and are located on the ELEC PWR panel on the overhead panel. The VENT EXTRACT pushbutton switch must be released-out. The pushbutton is located on the EQPT COOL section on the overhead panel. PITCH TRIM 1, YAW DAMPER 1 and must be rest by switching the respective engage levers to the 1 position. AP/FD 1 must be rest by switching the AP/FD 1 engage lever to the ON position. Pitch Trim and Yaw Damper engage levers are located on the FAC/ATS engage unit on the overhead panel. AP switch is located on the glareshield. Navigation Display 1 must be set on ROSE mode by turning the left-hand ND MODE rotary selector to ROSE. The selector is located on the glareshield. The landing gear POSTION DET switch must be set to the SYS 1 position. The switch is located on the center instrument panel. If required, the air conditioning packs are set to manual by releasing out the PACK 1 and PACK 2 Mode select pushbuttons. The temperature can then be manually controlled by turning the pack discharge COLD/HOT selector. The PACK mode select pushbuttons and the COLD/HOT selectors are located on the Pack Temp Panel on the overhead panel.

Manifestation after correct completion of the procedure: Depressing both OVRD SUPPLY switches cuts off AC bus 1, AC bus 2, and the DC NORM bus. The right-hand PFD/ND is not indicating, the right-hand altimeter is not indicating. ECAM displays are not available. There may be other abnormal indications due to the fact that AC bus 1, AC bus 2, and the DC NORM bus are off line. APU GEN pushbutton has white illuminated OFF/R caption. Pushbutton is located on the ELEC PWR panel on the overhead panel. Both OVRD SUPPLY switches have illuminated white ON caption. The VENT EXTRACT pushbutton has white illuminated OVBD caption. The pushbutton is located on the EQPT COOL section on the overhead panel. PACK mode select pushbuttons have white illuminated MAN caption. Both pushbuttons are located on the Pack Temp Panel on the overhead panel.

Aircraft type: Airbus A310
Failure case: DC norm bus short circuit.
Failure manifestation: Single chime. ELEC, FLT CTL, ATS, FUEL and ANTI ICE lights illuminate amber on the Warning Light Display Panel on the central instrument panel. The left ECAM display shows the DC NORM BUS OFF procedure. The right ECAM display shows the ELEC/DC page. The DC NORM BUS OFF light illuminates amber on the ELEC PWR panel on the overhead panel. Pushbutton lighting on the overhead panel is lost to a great extent.
AOM procedure:

```
DC NORM BUS OFF
AVOID ICING CONDITIONS
LAND RECOVERY.................................................ON
Affected eqpt................................................OFF
     RUD TRAVEL 2
     PITCH FEEL 2
     SPLR 3 & 2,5
     WING ANTI ICE
     FUEL PUMPS (all except L + R OUTR 2)
     L+R WINDOW HEAT
LDG SPD INCREMENT.........................................+ 10 KT
LDG DIST.........................................MULTIPLY BY 1.4
BUS EQPT LIST..............................................CHECK
FUEL GRAVITY FEEDING PROC..................................APPLY
NOSEWHEEL STEERING INOPERATIVE PROCEDURE....................APPLY
```

Alert inhibition: 70 kt - 400 ft, landing - 70 kts.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The LAND RECOVERY pushbutton must be pushed to ON. The pushbutton is located on the ELEC PWR panel on the overhead panel. Affected equipment must be switched off by releasing out the following pushbuttons: RUD TRAVEL 2, SPLR 2&3, SPLR 5, PITCH FEEL 2, ANTI ICE ENG 1, ANTI ICE ENG 2, ANTI ICE WING SUPPLY, L INR TK PUMP 1, L INR TK PMP 2, R INR TK PUMP 1, R INR TK PUMP 2, L CTR TK PUMP, R CTR TK PUMP, L OUTR TK PUMP 1, R OUTR TK PUMP 1, L WINDOW HEAT, R WINDOW HEAT. All pushbuttons are located on the overhead panel.

Note: Pushbutton lighting on the overhead panel is largely lost. Consequently, when selecting affected equipment to OFF, action feedback may only be provided on the ECAM.
Manifestation after correct completion of the procedure: ELEC, FLT CTL, ATS, FUEL, and ANTI ICE lights illuminate amber on the Warning Light Display Panel on the central instrument panel. The DC NORM BUS OFF light illuminates amber on the ELEC PWR panel on the overhead panel. Feedback on switching off the affected equipment is provided on ECAM.

Aircraft type: Airbus A310
Failure case: Landing gear position detect failure.
Failure manifestation: The landing gear lever will not move up after takeoff. Single chime. L/G WHEEL light illuminates amber on the Warning Light Display Panel on the central instrument panel. L/G LEVER INTERLOCKED procedure is displayed on the left ECAM display.
AOM procedure:

```
L/G LEVER INTERLOCKED
L/G POS DET SYS.........................................OTHER SYS
If second attempt unsuccessful:
     L/G LEVER...........................................DOWN
     MAX SPEED...........................................270
```

Alert inhibition: Electrical power on - takeoff, 1000 ft - 5 min after engine shutdown.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The L/G POS DET SYS toggle switch must be set to the other position (2 when in 1, 1 when in 2). This switch is located on the landing gear panel on the central instrument panel. If the fault remains the landing gear must remain down.
Manifestation after correct completion of the procedure: The landing gear lever is in the down position. L/G WHEEL light illuminates amber on the Warning Light Display Panel on the central instrument panel.

Aircraft type: Airbus A310
Failure case: Left-hand reverser unlock inflight.
Failure manifestation: Single chime. ENG 1 illuminates amber on the Warning Light Display Panel. The REVERSE UNLK procedure is presented on the left ECAM display, the ENG page is presented on the right ECAM display. The left-hand REV UNLK light illuminates amber on the central instrument panel. Abnormal aircraft behavior may be exhibited by buffeting, vibration, and rolling.
AOM procedure:

```
ENG REV UNLK
IF BUFFET OR BANK
     THROTTLE................................................IDLE
     FUEL LEVER...............................................OFF
     MAX SPD..................................................240
     SINGLE ENG OPER PROC...................................APPLY
```

Alert inhibition: Elec pwr on - first engine to power, 70 kts- 400 ft, landing - 5 min after first engine shut down.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The flight crew must determine if the failure annunciation is genuine or a false warning by assessing secondary cues. In case of a genuine failure, the thrust lever of the affected engine must be moved to the idle position. The corresponding fuel lever must be moved to the OFF position. Both levers are located on the pedestal.
Manifestation after correct completion of the procedure: The left-hand REV UNLK light illuminates amber on the central instrument panel. Left-hand engine indicators show values corresponding with inoperative engine. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

Aircraft type: Airbus A310
Failure case: IRS 1 failure.
Failure manifestation: Single chime. NAV ADC light illuminates flashing amber on the Warning Light Display Panel. ATS and FLT CTL lights illuminate steady amber on the Warning Light Display panel on the central instrument panel. Left ECAM displays the IRS FAULT procedure. HDG flag on RMI/VOR 1 and RMI/ADF 2. IVS flag on VSI 1. Various flags on PFD 1 and ND 1. In case or data failure, the whole sphere on the PFD is erased. In case of attitude or pitch information discrepancy, an amber CHECK ATT appears on both PFD's. RMI/VOR 1, VSI 1, PFD 1and ND 1are located on the left main instrument panel. RMI/ADF 2 is located on the right main instrument panel.
AOM procedure:

```
IRS FAULT
IRS 1 or 2
     CAPT (F/O) ATT/HDG.....................................SYS 3
IRS 3
     ATT/HDG ON SYS 3..................................DO NOT USE
```

Alert inhibition: 70 kts - 400 ft, 400 ft - 70 kts.
Incorrect or possibly misleading information: In case of data failure, the whole sphere on the PFD is erased. In case of attitude or pitch information discrepancy, CHECK ATT appears in amber on both PFD's but the sphere remains.
Description of required action: The Captain must select ATT/HDG system 3 by pressing-in the ATT HDG pushbutton on the CAPT SWITCHING panel on the main instrument panel.
Manifestation after correct completion of the procedure: SYS 3 light illuminates white in the ATT HYD pushbutton on the CAPT SWITCHING panel. CAPT/3 light illuminates green on the ATT HDG pushbutton on the F/O switching panel.

Aircraft type: Airbus A310
Failure case: Green hydraulic system leak.
Failure manifestation: Green reservoir quantity indicator drops. Indicator is located on the HYD PWR panel on the overhead panel. When the pointer drops to or below the red dot, the ECAM system is activated: Single chime, amber HYD light on the Warning Light Display Panel. RSVR LO LEVEL procedure on the left ECAM, HYD page on the right ECAM.
AOM procedure:

```
HYD RSVR LO LEVEL
PUMP(S) AFFECTED.............................................OFF
Affected eqpt................................................FF
     BLUE:.........................................SPLRS 3 & 2,7
     YELLOW:.........................PITCH FEEL 2, SPLRS 4 & 1,6
     GREEN:..............................PITCH FEEL 1, SPLR 5
Affected SYS:
BLUE or YELLOW:
     LDG DIST.....................................MULTIPLY BY 1.2
GREEN
     LDG SPD INCREMENT...................................+ 10 KT
     LDG DIST.....................................MULTIPLY BY 1.2
     L/G GRAVITY EXT PROC...................................APPLY
```

Alert inhibition: 70 kts - 1000 ft, 400 ft - 70 kts.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Green hydraulic pumps are switched off by releasing-out the ELEC PUMPS pushbutton and the Green ENG 1 and Green ENG 2 pushbutton. Pushbuttons are located on the HYD PWR panel on the overhead panel. PITCH FEEL 1 and SPLR 5 are switched off by releasing out the respective pushbuttons located on the overhead panel.
Manifestation after correct completion of the procedure: The ELEC PUMPS, Green ENG 1, Green ENG 2, PITCH FEEL 1 and SPLR 5 pushbuttons have illuminated white OFF caption.

Aircraft type: Airbus A310
Failure case: LP compressor bearing collapse (engine 1).
Failure manifestation: Rapid decrease of N1 to 0. EGT increases rapidly. Loud bang, Sudden high-frequency vibration, decreasing as N1 slows down. Engine vibration indicator shows high level. Engine flameout approximately 30 seconds after the seizure. N2 goes to windwilling value, EGT slowly decreases to ambient temperature. When N2 drops below 54.2%: single chime, ENG 1 illuminates amber on the warning light display panel. ENG FAIL procedure is displayed on left ECAM. ENG page is displayed on right ECAM.
AOM procedure:

```
ENGINE FAIL
INGNITION...........................................CONT RELIGHT
THROTTLE....................................................IDLE
If no immediate relight
     FUEL LEVER..............................................OFF
IF DAMAGE
     FIRE HANDLE............................................PULL
     1ST AGENT (AFTER 10 s if inflight) .....................DISCH
SINGLE ENGINE OPER PROC....................................APPLY
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Rotate the ENG START selector switch to the CONT RELIGHT position. The switch is located on the ENG START panel on the overhead panel. Retard the left-hand throttle to the idle position. Switch the left-hand fuel lever to the OFF position. Throttle and fuel lever are located on the pedestal. Pull the ENG FIRE handle of the left-hand engine. Press either AGENT 1 or 2 pushbutton to discharge a fire extinguisher bottle. The Fire handle and pushbutton are located on the overhead panel.
Manifestation after correct completion of the procedure: N1 indicator of affected engine shows 0. N2 indicator shows windmilling value. EGT reducing to ambient temperature. Throttle of left-hand engine in idle position, fuel lever closed. ENG 1 fire handle is pulled. Left-hand engine AGENT 1 or 2 pushbutton has amber illuminated DISCH caption. Left-hand engine indicators show values corresponding with inoperative engine. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

B.7 BOEING 777.

Aircraft type: Boeing 777
Failure case: Air data system failure.
Failure manifestation: A NAV AIR DATA SYS message is displayed in amber on the EICAS. Left and right PFD may show different speed or altitude.
AOM procedure:

[] NAV AIR DATA SYS

PFDs AND STANDBY DISPLAYS..............................CROSSCHECK

Alert inhibition: EICAS massage is inhibited during takeoff from 80 kts up to 400 ft radio altitude or 20 seconds after rotation, whichever comes first. During landing from 200 ft radio altitude up to 75 kts or 40 seconds elapse or 800 ft radio altitude, whichever comes first.
Incorrect or possibly misleading information: Left or right PFD may show incorrect speed or altitude until alternate source is selected.
Description of required action: Crosscheck airspeed and altitude on the PFDs and standby displays for accuracy. Each display is receiving data from an independent source. Select the alternate air data/attitude source if airspeed or altitude on the respective PFD is determined to be in error. Selecting alternate source is done by switching the AIR DATA/ATT pushbutton on the left and right forward panel.
Manifestation after correct completion of the procedure: ALTN is visible in the AIR DATA/ATT pushbutton if it is switched to alternate source.

Aircraft type: Boeing 777
Failure case: Attitude and air data reference unit failure.
Failure manifestation: Master caution light illuminates amber. Beeper sounds. NAV ADIRU INERTIAL message in amber on EICAS. ND map display orientation changes from heading up to track up. A SET HDG prompt appears on the POS INIT page of the CDU three minutes after the ADIRU failure. The three CDUs are located on the forward (2) and aft (1) aisle stand.
AOM procedure:

```
[] NAV ADIRU INERTIAL
TRANSPONDER ALTITUDE SOURCE SELECTOR.........................ALTN
When heading no longer displayed and SET HDG line displayed
on POS INIT page 1/3:
     HEADING...........................................ENTER
     AUTOPLIOT.....................................RE-ENGAGE
```

Alert inhibition: During takeoff from 80 kts up to 400 ft radio altitude or 20 seconds after rotation, whichever comes first. During landing from 200 ft radio altitude up to 75 kts or 40 seconds elapse or 800 ft radio altitude, whichever comes first.
Incorrect or possibly misleading information: Heading drift is possible.
Description of required action: The Secondary Attitude and Air Data Reference Unit (SAARU) is selected as air data source for transponder altitude reporting by selecting the TRANSPONDER ALTITUDE SOURCE SELECTOR on the aft aisle stand panel to ALT SOURCE. The flight crew enter magnetic compass heading information into the CDU POS INIT page using the CDU keyboard, and the autopilot is reengaged. The flight crew crosschecks the heading periodically for drift with the magnetic compass and updates heading as necessary.
Manifestation after correct completion of the procedure: CHECKLIST COMPLETE is displayed as white text on a green background on the MFD. [] symbol in front of NAV ADIRU INERTIAL message on EICAS has disappeared.

Aircraft type: Boeing 777
Failure case: AC bus fault resulting in electrical smoke.
Failure manifestation: Electrical smoke.
AOM procedure:

ELECTRICAL SMOKE

```
OXYGEN MASKS AND SMOKE GOGLES..................................ON
CREW COMMUNICATIONS.....................................ESTABLISH
RECIRCULATION FAN SWITCHES (Both)..............................OFF
If smoke/fumes/fire source known:
     ELECTRICAL POWER (affected equipment).................REMOVE
If smoke persists or source unknown:
     IN-FLIGHT ENTERTAINMENT SYSTEM / PASSENGER SEATS POWER
     SWITCH.....................................................OFF
     CABIN/UTILITY POWER SWITCH...............................OFF
     Plan to land at the nearest suitable airport.
```

Alert inhibition: Not applicable.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Crew dons oxygen masks and smoke goggles and establishes communication. Both recirculation fan pushbuttons are switched to the OFF position. These pushbuttons are located on the Air Conditioning panel on the Overhead Panel. The IFE/PASS SEATS and the CABIN/UTILITY pushbuttons switched to OFF. Both pushbuttons are located on the Electrical Panel on the overhead panel.
Manifestation after correct completion of the procedure: UPPER and LOWER RECIRC FANS pushbuttons have a horizontal line illuminated. IFE/PASS SEATS pushbutton and CABIN/UTILITY pushbutton have amber OFF lights illuminated.

Aircraft type: Boeing 777
Failure case: AC Bus L failure.
Failure manifestation: Master caution light illuminates amber on the glareshield panel. Beeper. [] ELEC AC BUS L message appears in amber on the EICAS display on the center forward panel.
AOM procedure:

```
ELEC AC BUS L
GENERATOR CONTROL SWITCH.............................OFF, THEN ON
     Attempt only one reset
IF ELEC AC BUS message remains displayed:
     APU SELECTOR...........................START, RELEASE TO ON
     Do not accomplish the following checklist:
     ELEC GEN OFF
     If ELEC AC BUS message remains displayed after APU running:
          BUS TIE SWITCH(affected side)............OFF, THEN AUTO
          Attempt only one reset
          IF ELEC AC BUS message remains displayed:
               Do not accomplish the following checklists:
               WINDOW HEAT
               HYD PRESS PRI.
```

Alert inhibition: During takeoff from 80 kts up to 400 ft radio altitude or 20 seconds after rotation, whichever comes first. During landing from 200 ft radio altitude up to 75 kts or 40 seconds elapse or 800 ft radio altitude, whichever comes first.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: By pushing the CHKL pushbutton on the display select panel on the glareshield the appropriate checklist is automatically displayed on the multi function display on the forward aisle stand. The crew pushes the L GEN CTRL pushbutton on the electrical panel on the overhead panel to OFF and then to ON again. If the ELEC AC BUS L remains displayed on the EICAS the crew starts the APU by rotating the APU rotary select switch on the electrical panel on the overhead panel to START and releasing it to the ON position. Correct operation of the APU is observed on the APU Status Display on the multifunction display on the forward aisle stand. If the ELEC AC BUS L message still remains the flight crew resets the L BUS TIE SWITCH by pushing the L BUS TIE pushbutton on the electrical panel on the overhead panel to OFF and then to AUTO.
Manifestation after correct completion of the procedure: CHECKLIST COMPLETE is displayed as white text on a green background on the MFD. [] symbol in front of ELEC AC BUS L message on EICAS has disappeared. L GEN CTRL and L BUS TIE pushbuttons have illuminated status caption (ON, OFF or AUTO). APU operation (if applicable) is indicated on the multifunction display.

Aircraft type: Boeing 777
Failure case: Leak in left hydraulic system.
Failure manifestation: HYD QTY LOW L advisory message appears in amber on the EICAS. If the STAT display switch on the display select panel is pushed, the HYD synoptic switch will appear on the multifunction display. The L system reservoir quantity shows an abnormal low value, accompanied by a LO caption in amber. The quantity keeps dropping and at certain moment the master caution light illuminates in amber, the beeper sounds and the HYD PRESS SYS L caution appears in amber on the EICAS.
AOM procedure:

[] HYD PRESS SYS L

LEFT DEMAND PUMP SELECTOR......................................ON

If HYD PRESS SYS L message remains displayed:

LEFT PRIMARY PUMP SWITCH................................OFF

LEFT DEMAND PUMP SELECTOR...............................OFF

Note: left thrust reverser is inoperative:

Note: Roll rate may be reduced inflight. Speedbrakes effectiveness may be reduced inflight and during landing.

Do not accomplish the following checklist: SPOILERS

Alert inhibition: During takeoff from 80 kts up to 400 ft radio altitude or 20 seconds after rotation, whichever comes first. During landing from 200 ft radio altitude up to 75 kts, or 40 seconds elapse or 800 ft radio altitude, whichever comes first.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: By pushing the CHKL pushbutton on the display select panel on the glareshield the appropriate checklist is automatically displayed on the multifunction display on the forward aisle stand. The crew turns the left DEMAND pump selector rotary knob on the hydraulics panel on the overhead panel to the ON position. As the HYD PRESS SYS L message remains displayed on EICAS, the crew switches of the left primary pump by pressing the L ENG PRIMARY pushbutton on the hydraulic panel on the overhead panel, and switches off the left demand pump by rotating the left DEMAND pump selector rotary knob on the hydraulics panel on the overhead panel to the OFF position.
Manifestation after correct completion of the procedure: CHECKLIST COMPLETE is displayed as white text on a green background on the MFD. [] symbol in front of HYD PRESS SYS L message on EICAS has disappeared.

Aircraft type: Boeing 777
Failure case: Ground/flight sensors remain in ground.
Failure manifestation: Gear lever locked down.
AOM procedure:
GEAR LEVER LOCKED DOWN
LOCK OVRD SWITCH....................................PUSH AND HOLD
LANDING GEAR LEVER..UP
Alert inhibition: Not applicable.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Push and hold the landing gear lever override switch, located on the landing gear panel on the center forward panel, while moving the landing gear lever to UP.
Manifestation after correct completion of the procedure: Landing gear selector lever up.

Aircraft type: Boeing 777
Failure case: LP compressor bearing collapse (left engine).
Failure manifestation: Rapid decrease of N1 to 0. EGT increases rapidly. Loud bang, sudden high-frequency vibration, decreasing as N1 slows down. Engine flameout approximately 30 seconds after the seizure. EGT slowly decreases to ambient temperature. Beeper sounds, master caution light illuminates amber in the glareshield panel. ENG FAIL L message appears in amber on the EICAS.
AOM procedure:

ENGINE SEVERE DAMAGE

AUTOTHROTTLE ARM SWITCH.......................................OFF
THRUST LEVER..CLOSE
FUEL CONTROL SWITCH......................................CUTOFF
ENGINE FIRE SWITCH...PULL
If high airframe vibration occurs and continues after engine shutdown:

Without delay, reduce airspeed and descend to a safe altitude which results in an acceptable vibration level. If high vibration returns and further airspeed reduction and descent in not practical, increasing the airspeed may reduce the vibration.

APU SELECTOR.................................START, RELEASE TO ON
TRANSPONDER MODE SELECTOR................................TA ONLY
Plan to land at the nearest suitable airport.
If landing using flaps 20:

GROUND PROXIMITY FLAP OVERRIDE SWITCH..................OVRD
Note: Use flaps 20 and VREF20 for landing and flaps 5 for go-around

If landing using flaps 30 (performance permitting)

Note: Use flaps 30 and VREF30 for landing and flaps 20 for go-around

Alert inhibition: Master caution light and beeper are inhibited during takeoff from 80 kts up to 400 ft radio altitude or 20 seconds after rotation, whichever comes first. During landing from 200 ft radio altitude up to 75 kts, or 40 seconds elapse or 800 ft radio altitude, whichever comes first.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Move the autothrottle arm toggle switch to the OFF position. The switch is located on the mode control panel on the glareshield panel. Retard the left-hand throttle to the close position. Switch the left fuel control switch to the CUTOFF position. Throttle and fuel control switch are located on the pedestal. Pull the left ENG FIRE switch, this switch is located on the aft aisle stand. Start the APU by rotating the APU rotary select switch on the electrical panel on the overhead panel to START and releasing it to the ON position. Rotate the Transponder mode selector on the aft aisle stand to the TA ONLY position.
Manifestation after correct completion of the procedure: Throttle of left-hand engine in idle position, left fuel control switch closed. Left ENG FIRE1 fire switch is pulled. Left-hand engine indicators show values corresponding with inoperative engine. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

Aircraft type: Boeing 777
Failure case: Fuel leak at the left engine.
Failure manifestation: One or more of the following: Observation of fuel spray from the engine or engine strut, excessive engine fuel flow, fuel quantity decreasing at an abnormal rate, FUEL IMBALANCE EICAS message, FUEL DISAGREE message on the CDU scratchpad, INSUFFICIENT FUEL message on the CDU scratchpad.
AOM procedure:

```
FUEL LEAK
CENTER FUEL PUMP SWITCHES (BOTH).............................OFF
CROSSFEED SWITCHES (BOTH)..................................CLOSE
If both main tank quantities decrease at the same rate:
Do not use center tank fuel.  Fuel leak may be from the center
tank to the center wing area.
CDU PROGRESS 2/2 PAGE.....................................SELECT
CALCULATED FUEL.......................................SELECT USE
DESTINATION FUEL ESTIMATE..................................CHECK
If both main tank quantities are not decreasing at the same
rate:
CDU PROGRESS PAGE 2/2.....................................SELECT
TOTALIZER.............................................SELECT USE
A/T ARM SWITCH (AFFECTED ENGINE).............................OFF
THROTTLE (AFFECTED ENGINE)................................. IDLE
FUEL CONTROL SWITCH (AFFECTED ENGINE).............CONFIRM, CUTOFF
APU (IF AVAILABLE)..........................START, RELEASE TO ON
TRANSPONDER MODE SELECTOR.................................TA ONLY
LAND AT THE NEAREST SUITABLE AIRPORT
GND PROX FLAP OVRD SWITCH...................................OVRD
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: The FUEL IMBALANCE procedure requires switching the crossfeed ON, contrary to what is required in case of a fuel leak. This may result in confusion, particularly because FUEL IMBALANCE is annunciated while FUEL LEAK is not annunciated.
Description of required action: Both center fuel pumps must be switched OFF by depressing the L and R CENTER PUMPS on the fuel panel on the overhead panel. Both crossfeed switches must be closed by depressing the FWD and AFT CROSSFEED pushbuttons on the fuel panel on the overhead panel. It must be determined if both main tank quantities decrease at the same time or not. In this case (leak in the vicinity of the engine), the PROGRESS 2/2 page must be selected on the FMC and TOTALIZER USE prompt must be selected so that the FMC uses this value. The left engine must be secured by retarding the throttle level to idle and moving the fuel control switch to the cutoff position.
Manifestation after completion of the procedure: L and R CENTER PUMPS pushbuttons on the fuel panel on the overhead panel are dark (ON not visible). Bar is nor visible on FWD and AFT CROSSFEED pushbuttons on the fuel panel on the overhead panel. Indications associated with the left engine inoperative.

B.8 AIRBUS A330.

Aircraft type: Airbus A330
Failure case: Failure of Air Data Reference (ADR) nr 2.
Failure manifestation: Single chime, master caution light. ADR FAULT message on ECAM. FAULT light illuminates amber in the ADR pushbutton on the overhead panel. A red SPD flag replaces airspeed on the co-pilot's PFD. A red ALT flag replaces the altitude scale on the co-pilot's PFD.
AOM procedure:
ADR 2 FAULT
AIR DATA SWTG..F/O ON 3
ADR 2..OFF
Alert inhibition: Takeoff 80 kts - liftoff, landing touchdown - 80 kts
Incorrect or possibly misleading information: No incorrect or misleading information.
Description of required action: The Air Data select switch on the pedestal must be switched to the F/O ON 3 position. The ADR 2 pushbutton on the overhead panel must be switched OFF.
Manifestation after correct completion of the procedure: White OFF light illuminated in the ADR 2 pushbutton on the overhead panel. ADIRS SWTG message appears in green on the memo display.

Aircraft type: Airbus A330
Failure case: Failure of Inertial Reference (IR) 1.
Failure manifestation: Single chime, master caution light. NAV IR 1 FAULT message on ECAM. FAULT light illuminates amber in the IR1 pushbutton on the overhead panel. Red ATT flag on the PFD, red HDG flag on the ND. GPWS TERR amber light illuminates on the overhead panel.
AOM procedure:

```
IR 1 FAULT
ATT HDG SWTG...........................................CAPT ON 3
If IR available in ATT mode:
     IR MODE SEL.............................................ATT
     Aircraft attitude and heading may be recovered by applying
     the IR ALIGNMENT IN ATT MODE procedure
If IR totally faulty
     IR......................................................OFF

IR ALIGNMENT IN ATT MODE
MODE SELECTOR................................................ATT
LEVEL A/C ATTITUDE..........................................HOLD
CONSTANT A/C SPEED..........................................HOLD
MCDU INITIALIZATION:
     DATA (MCDU KEY).......................................PRESS
     IRS MONITOR (2L KEY)..................................PRESS
     A/C HEADING...........................................ENTER
CDU INITIALIZATION
     DISPLAY SYS SWITCH..............................AFFECTED SYS
     DISPLAY DATA SWITCH.....................................HDG
     H KEY.................................................PRESS
     A/C HEADING...........................................ENTER
Due to IR drift, the magnetic heading must be periodically
crosschecked with the standby compass and updated, if required
```

Alert inhibition: In takeoff from 80 kts to 1500 ft. In landing from 800 ft to 80 kts.
Incorrect or possibly misleading information: No incorrect or misleading information.
Description of required action: The ATT HDG select switch on the pedestal must be switched to the CAPT ON 3 position. An attempt may be made to recover aircraft heading and attitude by selecting the IR1 MODE SELECTOR switch on the overhead panel to ATT. The aircraft must stay level, with a constant speed for 30 seconds. The aircraft's magnetic heading must be entered into the system. It has to be reset frequently (approximately every 10 minutes) because of IR drift. If it is not possible to recover aircraft attitude and heading the IR 1 pushbutton on the overhead panel must be switched OFF.
Manifestation after correct completion of the procedure: In case attitude and heading not recovered: White OFF light illuminated in the IR 1 pushbutton on the overhead panel.

Aircraft type: Airbus A330
Failure case: Leak in blue hydraulic system.
Failure manifestation: Master caution light. Single chime. B RSVR LO LVL message in amber on ECAM. HYD page is called on the System Display, with amber quantity indication. FAULT lights illuminate amber in the ENG 1 and BLUE ELEC PUMP pushbuttons on the HYD panel on the overhead panel.
AOM procedure:

```
B RSVR LO LVL
BLUE PUMPS (ENG 1 + ELEC).....................................OFF
LDG DIST PROC...............................................APPLY
SLATS SLOW
CAT 3 SINGLE ONLY
Note:  following a blue hydraulic system failure the parking
brake may be inoperative due to blue accumulator low pressure.
```

Alert inhibition: 80 kts - 1500 ft in takeoff, 800 ft - 80 knot in landing.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: The pumps that pressurize the system are switched off by pushing the ENG 1 and ELEC pushbuttons for the blue system. The pushbuttons are located on the hydraulics panel on the overhead panel. The landing distance must be multiplied by a factor of 1.20.
Manifestation after correct completion of the procedure: OFF lights illuminate white in the ENG 1 and BLUE ELEC PUMP pushbuttons on the HYD panel on the overhead panel. HYD system display page indicates that for the blue system the pumps are off, reservoir quantity is low and pressure is low.

Aircraft type: Airbus A330
Failure case: LP compressor bearing collapse (engine 1).
Failure manifestation: Rapid decrease of N1 to 0. EGT increases rapidly. Loud bang, sudden high-frequency vibration, decreasing as N1 slows down. Engine vibration indicator shows high level. Engine flameout approximately 30 seconds after the seizure. N2 goes to windmilling value, EGT slowly decreases to ambient temperature. Master caution light. Single chime. ENG 1 FAIL procedure is displayed on the Engine/Warning display, ENG page is displayed on the System Display.
AOM procedure:

```
ENG 1 FAIL
ENG START SEL................................................IGN
THROTTLE....................................................IDLE
IF NO ENG RELIGHT AFTER 30 s
     ENG MASTER (affected engine)............................OFF
IF DAMAGE
     ENG FIRE PUSHBUTTON (affected engine)..................PUSH
     AGENT 1 AFTER 10 s....................................DISCH
     L+R INR TK SPLIT.........................................ON
```

Alert inhibition: No inhibition.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Rotate the ENG START selector switch to the IGN START position. The switch is located on the pedestal. Retard the left-hand throttle to the idle position. Switch the left-hand ENG MASTER switch to the OFF position. Throttle and switch are located on the pedestal. Push the ENG 1 FIRE pushbutton and after 10 seconds push the AGENT 1 pushbutton. Both pushbuttons are located on the overhead panel. Push the left and right INNER TK SPLIT pushbuttons on the overhead panel to ON. These pushbuttons are guarded.
Manifestation after correct completion of the procedure: N1 indicator of affected engine shows indicates 0. N2 indicator shows windmilling value. EGT reducing to ambient temperature. Throttle of left-hand engine in idle position, master switch closed. When the ENG 1 fire pushbutton is pushed, the left AGENT 1 pushbutton caption SQUIB comes on white. The DISCH caption illuminates amber when the AGENT 1 pushbutton is pushed. The L and R INNER TK SPLIT pushbuttons white ON lights are illuminated. Left-hand engine indicators show values corresponding with inoperative engine. Possible remaining abnormal electric and hydraulic indications due to the inoperative engine.

Aircraft type: Airbus A330
Failure case: DC bus 2 short circuit.
Failure manifestation: Single chime, amber master caution light, DC BUS 2 FAULT message in amber and associated procedure on the Engine/Warning display, Electrical page DC on the System Display. Secondary indications include amber FAULT lights on the overhead panel for SEC 2, PRIM 2, T.TANK MODE, L1 FUEL Pump and R 1 FUEL PUMP.
AOM procedure:

```
ELEC DC BUS 2 FAULT
AIR DATA SWTG (IF ADR 3 AVAIL)..........................F/O ON 3
FM SOURCE..............................................BOTH ON 1
SEC 2...................................................KEEP ON
IF CG AFT 32 % AND WHEN SPD > 270 KT AND NOT IN CLIMB:
     T TANK MODE...............................................FWD
```

Alert inhibition: In takeoff from 80 kts to liftoff, in landing from touchdown to 80 kts.
Incorrect or possibly misleading information: The SEC 2 fault light comes on amber but SEC 2 is functioning properly. SEC 2 is normally supplied by DC BUS 2,. In case of a DC BUS 2 failure, the DC ESS BUS supplies SEC 2. Selecting SEC 2 OFF would result in a loss of the SEC 2 backup power supply.
Description of required action: The AIR DATA rotary selector is set to F/O ON 3, the FM rotary selector is set to BOTH ON 1. Both switches are located on the pedestal. If cg is aft of 32% and the speed is grater than 270 knots and the aircraft is not climbing, the T TANK mode pushbutton on the overhead panel must be pushed to FWD.
Manifestation after correct completion of the procedure: Status page on the System Display shows list of inoperative systems. Several secondary amber FAULT lights remain illuminated on the overhead panel.

Aircraft type: Airbus A330
Failure case: AC bus 2 short circuit resulting in electrical smoke.
Failure manifestation: Electrical smoke.
AOM procedure:

SMOKE/FUMES/AVNCS SMOKE

```
VENT EXTRACT.............................................OFF
CAB FANS.................................................OFF
GALLEYS..................................................OFF
SIGNS.....................................................ON
CKPT/CABIN COM.....................................ESTABLISH
IF REQUIRED
     CREW OXY MASKS.................................ON/100%/EMERG
IF SMOKE SOURCE IMMEDIATELY OBVIOUS, ACCESSIBLE AND
EXTINGUISHABLE:
     FAULTY EQPT.......................................ISOLATE
IF SMOKE SOURCE NOT IMMEDIATELY ISOLATED:
     DIVERSION........................................INITIATE
     DESCENT..........................................INITIATE
AT ANY TIME OF THE PROCEURE, IF SMOKE/FUMES BECOMES THE GREATEST
THREAT:
     SMOKE REMOVAL....................................CONSIDER
     ELEC EMER CONFIG.................................CONSIDER
AT ANY TIME OF THE PROCEDURE, IF SITUATION BECOMES UNMANAGEABLE:
     IMMEDIATE LANDING................................CONSIDER
IF AIR COND SMOKE SUSPECTED
     APU BLEED.............................................OFF
     VENT EXTRACT.........................................AUTO
     PACK 1................................................OFF
     If smoke continues:
          PACK 1............................................ON
          PACK 2...........................................OFF
          CRG FWD ISOL VALVE...............................OFF
          If smoke still continues:
               PACK 2.......................................ON
               VENT EXTRACT...............................OVRD
     SMOKE/FUMES REMOVAL..............................CONSIDER
IF CABIN EQUIPMENT SMOKE SUSPECTED:
     PAX SYS...............................................OFF
     If smoke continues:
          EMER EXIT LT......................................ON
          COMMERCIAL.......................................OFF
          SMOKE DISSIPATION..............................CHECK
          FAULTY EQPT............................SEARCH/ISOLATE
          If smoke still continues or when faulty equipment
          confirmed isolated:
               COMMERCIAL.................................NORM
               PAX SYS....................................NORM
```

```
     SMOKE/FUMES REMOVAL................................CONSIDER
IF  SMOKE  SOURCE  CANNOT  BE  DETERMINED  AND  STILL  CONTINUES  OR
AVIONICS/ELECTRICAL SMOKE SUSPECTED:
     Shed AC BUS 1 as follows:
          GEN 2.........................................CHECK ON
          ECAM/ND SEL........................................F/O
          ELEC/AC page....................................SELECT
          BUS TIE............................................OFF
          AC ESS FEED.......................................ALTN
          GEN 1..............................................OFF
          SMOKE DISSIPATION................................CHECK
          If smoke continues:
               GEN 1..........................................ON
               AC ESS FEED..................................NORM
               ECAM/ND SEL..................................NORM
     Shed AC BUS 2 as follows:
          GEN 1.........................................CHECK ON
          BUS TIE......................................CHECK OFF
          AC ESS FEED.................................CHECK NORM
          ECAM/ND SEL.................................CHECK NORM
          GEN 2..............................................OFF
          SMOKE DISSIPATION................................CHECK
          If smoke continues:
               GEN 2..........................................ON
               BUS TIE........................................ON
     SMOKE/FUMES REMOVAL................................CONSIDER
IF SMOKE CONTINUES AND SOURCE CANNOT BE ISOLATED:
     ELEC EMER CONFIG...................................CONSIDER
     IMMEDIATE LANDING..................................CONSIDER
     TO SELECT ELEC EMER CONFIG:
          EMER ELEC PWR...................................MAN ON
     WHEN EMER GEN AVAIL:
          GEN 1..............................................OFF
          GEN 2..............................................OFF
          APU GEN............................................OFF
          APPLY EMER CONFIG PROCEDURE
```

<u>Alert inhibition</u>: Not applicable.
<u>Incorrect or possibly misleading information</u>: No incorrect or possibly misleading information.
<u>Description of required action</u>: Avionics ventilation air is extracted overboard by pushing the VENT EXTRACT pushbutton to OVRD. To prevent smoke from entering the cockpit and cabin, the fans are switched off by selecting the CAB FANS pushbutton to OFF. Both pushbuttons are located on the VENTILATION panel on the overhead panel. Galleys are switched off by pushing the GALLEY pushbutton on the electrical panel on the overhead panel to OFF. Seat belt sign, no smoking sign, and emergency exit lights are switched on by flipping the respective toggle switches on the Signs panel on the overhead panel to ON. Communication must be established with the cabin crew and if required the crew must don their oxygen masks.

When this has been done, the crew may either start a troubleshooting process to isolate the smoke source, or they may consider the set the electrical emergency configuration.

Manifestation after correct completion of the procedure: EXTRACT and CAB FANS pushbuttons on the VENTILATION panel on the overhead panel have illuminated OVRD and OFF indications. GALLEY pushbutton on the electrical panel on the overhead panel has illuminated OFF indication. Depending on the procedural path followed by the crew, electrical power has been removed from a number of systems.

Aircraft type: Airbus A330
Failure case: Failure of both landing gear control and interface units.
Failure manifestation: Single chime, master caution light illuminates amber on the glareshield. L/G LGCIU (1+2) FAULT message displayed on the Engine/Warning display, Wheel page presented on the System Display.
AOM procedure:

```
L/G LGCIU (1+2) FAULT
GPWS..........................................................OFF
FOR L/G EXTN:
     L/G NORMAL EXTN..........................................TRY
IF UNSUCCESSFUL
     L/G GRVTY EXTN ONLY
     FOR L/G GRVTY EXTN:
          MAX SPEED.........................................200KT

STATUS
INOP SYS
LGCIU 1+2
REVERSERS
N/W STEERING
GPWS
CAT 3 DUAL
```

Alert inhibition: During takeoff from 80 kts until 1500 ft, during landing from 800 ft until 80 kts.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Switch off the GPWS by pressing the GPWS SYS pushbutton on the overhead panel to OFF. When the landing gear must be extended for landing, the crew must first try to do this by the normal procedure, if this is unsuccessful the gravity extension procedure must be completed.
Manifestation after correct completion of the procedure: Engine/Warning display presents inoperative systems, System display presents Wheel page.

Aircraft type: Airbus A330
Failure case: Thrust reverser 1 unlocked inflight.
Failure manifestation: Single chime, master caution light, ENG 1 REV UNLOCKED message in amber on EICAS. REV indication appears in amber in the LP rotor speed (N1) indication on the ECAM's upper E/WD display. The indication first flashes for 9 seconds and then remains steady. Possibly buffet.
AOM procedure:

```
ENG 1 REV UNLOCKED (in-flight)
MAX SPEED.............................................300/0.82
THR LEVER (affected engine)...............................IDLE
IF BUFFET:
     MAX SPEED........................................250/0.70
     THR LEVER............................................IDLE
     ENG MASTER (affected engine)..........................OFF
ENG 1................................................SHUT DOWN
```

Alert inhibition: In landing from touchdown to 80 kts.
Incorrect or possibly misleading information: No incorrect or possibly misleading information.
Description of required action: Depending on the actual flying speed and whether buffet is encountered, it may be necessary to reduce the airspeed. The left-hand thrust lever is moved to idle, and in case of buffet, the left-hand ENG MASTER switched is moved to OFF. The shutdown procedure for engine 1 then needs to be completed.
Manifestation after correct completion of the procedure: Indication associated with engine 1 shut down.

B.9 SUMMARY OF RESULTS.

Fokker 100	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Fokker 100 static port 2 blocked	Yes	No	Yes	No	No	Yes	Crew	No	No	Yes	No	Yes	n/a	Yes
Fokker 100 cooling fan motor inop.	Yes	No	Yes	n/a	Yes	Prom	Crew	No	No	Yes	No	Yes	No	Yes
Fokker 100 AHRS system 1 failure	Yes	No	Yes	Yes	Yes	Prom	Crew	Yes	No	No	No	Yes	n/a	Yes
Fokker 100 AC bus 2 short circuit/smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	No	Yes
Fokker 100 DC bus 1 short circuit	Yes	Yes	Yes	No	Yes	Yes	Crew	No	No	Yes	No	Yes	No	Yes
Fokker 100 loss of both generators	Yes	No	No	n/a	No	Not	Crew	No	No	Yes	No	Yes	No	Yes
Fokker 100 hydraulic system 1 leak	Yes	No	Yes	n/a	Yes	Yes	Crew	No	Yes	No	No	Yes	Yes	Yes
Fokker 100 GND/FLT sensor in GND	Yes	No	Yes	No	Yes	Not	Crew	n/a	No	Yes	No	Yes	No	n/a
Fokker 100 anti-skid failure	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	No	No	Yes	Yes	No
Fokker 100 LP compr. bearing collapse	Yes	Yes	Yes	n/a	Yes	Yes	Crew	Yes	No	Yes	No	Yes	n/a	Yes
Fokker 100 fuel line leak	No	No	Yes	n/a	No	Yes	Time	No	No	No	No	Yes	n/a	Yes
Fokker 100 reverser unlocked	Yes	Yes	Yes	n/a	Yes	Prom	Crew	No	No	Yes	No	Yes	No	Yes

n/a = not applicable

Fokker F-27 Mk500	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F-27 static port 2 blocked	No	No	No	No	No	Not	n/a	No	No	Yes	No	Yes	n/a	Yes
F-27 LH vertical gyro failure	Yes	No	No	No	Yes	Not	n/a	No	No	No	No	Yes	n/a	Yes
F-27 inverter 1 short circuit/electrical smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	n/a	Yes
F-27 main DC bus short circuit	No	No	No	No	No	Not	n/a	No	No	Yes	No	No	n/a	Yes
F-27 pneumatic system leak	No	No	No	n/a	Yes	Not	n/a	No	No	Yes	Yes	Yes	n/a	Yes
F-27 GND/FLT sensor in GND	No	No	No	n/a	No	Not	n/a	No	No	No	No	No	No	Yes
F-27 engine oil leak	Yes	No	No	n/a	Yes	Not	Crew	No	No	Yes	No	Yes	No	Yes
F-27 flight fine lock elec. circuit failure	Yes	Yes	No	n/a	Yes	Not	Com pl	No	No	No	No	No	No	Yes

Fokker 50	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Fokker 50 AHRS 1 failure	Yes	No	Yes	No	Yes	Not	Crew	No	No	No	No	Yes	n/a	Yes
Fokker 50 DC bus 1 failure	Yes	No	Yes	n/a	No	Not	Crew	No	No	No	No	Yes	n/a	Yes
Fokker 50 AC bus 1 short circuit/ smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	No	Yes
Fokker 50 hydraulic system leak	Yes	No	Yes	n/a	Yes	Not	Crew	No	No	Yes	No	Yes	No	Yes
Fokker 50 GND/FLT sensor in GND	No	No	No	n/a	No	Not	n/a	No	No	No	No	No	n/a	Yes
Fokker 50 engine 1 oil leak	Yes	No	Yes	n/a	Yes	Not	Crew	Yes	No	Yes	No	Yes	n/a	Yes
Fokker 50 propeller electronic control fault	Yes	Yes	Yes	n/a	Yes	Not	Crew	Yes	No	Yes	No	Yes	No	Yes

Fokker F-28	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F-28 static port 2 blocked	No	No	No	No	No	Not	n/a	No	No	Yes	No	Yes	n/a	Yes
F-28 vertical gyro 1 failure	Yes	No	No	No	No	Not	n/a	No	No	No	No	No	n/a	Yes
F-28 AC bus 2 short circuit/electrical smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	No	Yes
F-28 TRU no. 2 overheat failure	No	No	No	n/a	Yes	Not	Com pl	No	No	No	No	No	n/a	Yes
F-28 hydraulic system 1 leak	No	No	No	n/a	No	Not	n/a	No	No	No	No	Yes	No	Yes
F-28 GND/FLT sensor in GND	No	No	No	n/a	No	Not	n/a	No	No	Yes	No	Yes	No	Yes
F-28 LP compressor bearing collapse	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	No	Yes	No	Yes
F-28 fuel line leak	No	No	No	n/a	No	Not	Com pl	No	No	No	No	Yes	n/a	Yes

Boeing 737-500	1	2	3	4	5	6	7	8	9	10	11	12	13	14
B-737 static port 2 blocked	No	No	No	No	No	Not	n/a	No	No	No	No	No	n/a	Yes
B-737 IRS 1 failure	Yes	No	No	No	No	Not	Crew	No	No	Yes	No	Yes	No	Yes
B-737 AC bus 2 short circuit/electr. smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	n/a	Yes
B-737 generator drive 1 low oil pressure	No	No	No	n/a	Yes	Not	Com pl	No	No	No	No	Yes	n/a	Yes
B-737 hydraulic system A leak	No	No	No	n/a	Yes	Not	Crew	No	No	No	No	No	No	Yes
B-737 GND/FLT sensor in GND	No	No	No	n/a	No	Not	n/a	No	No	Yes	No	No	No	Yes
B-737 LP compressor bearing collapse	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	No	Yes	No	Yes
B-737 reverser unlocked	Yes	Yes	No	n/a	Yes	Not	Com pl	No	No	Yes	No	Yes	n/a	n/a

Airbus A310	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A310 ADC 1 failure	Yes	No	Yes	Yes	No	Yes	Crew	No	No	No	No	Yes	n/a	Yes
A310 IRS 1 failure	Yes	No	Yes	Yes	Yes	Yes	Crew	No	No	No	No	Yes	n/a	Yes
A310 AC bus 2 short circuit/electr. smoke	Yes	Yes	Yes	n/a	Yes	Prom	Crew	No	No	Yes	Yes	Yes	No	Yes
A310 DC norm bus short circuit	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	No	No	Yes	No	Yes
A310 green hydraulic system leak	Yes	No	Yes	n/a	No	Yes	Crew	No	No	Yes	No	Yes	Yes	Yes
A310 LG pos detection failure	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	No	Yes
A310 LP compressor bearing collapse	Yes	Yes	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	Yes	Yes
A310 reverser unlocked	Yes	Yes	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	Yes	Yes

Boeing 777	1	2	3	4	5	6	7	8	9	10	11	12	13	14
B-777 air data system failure	Yes	No	Yes	No	No	Yes	Crew	No	No	No	No	Yes	n/a	Yes
B-777 ADIRU failure	Yes	No	Yes	No	Yes	Yes	Crew	No	No	No	No	Yes	Yes	Yes
B-777 AC bus 2 short circuit/electr. smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	n/a	Yes
B-777 AC bus L failure	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	n/a	Yes
B-777 hydraulic system L leak	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	Yes	Yes
B-777 GND/FLT sensor in GND	No	No	No	n/a	No	Not	n/a	No	No	No	No	No	n/a	Yes
B-777 LP compressor bearing collapse	Yes	Yes	Yes	n/a	Yes	Yes	Crew	No	No	No	No	Yes	Yes	Yes
B-777 fuel leak	No	No	No	n/a	No	Not	n/a	No	No	Yes	No	Yes	n/a	Yes

Airbus A330	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A330 ADR 2 failure	Yes	No	Yes	Yes	Yes	Yes	Crew	No	No	No	No	Yes	n/a	Yes
A330 IRS 1 failure	Yes	No	Yes	Yes	Yes	Yes	Crew	No	No	Yes	No	Yes	No	Yes
A330 AC bus 2 short circuit/electr. smoke	No	Yes	No	n/a	No	Not	n/a	No	No	Yes	Yes	No	n/a	Yes
A330 DC bus 2 short circuit	Yes	No	Yes	No	Yes	Yes	Crew	No	No	Yes	No	Yes	n/a	Yes

A330 blue hydraulic system leak	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	No	No	Yes	Yes	Yes
A330 LGCIU 1+2 failure	Yes	No	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	No	Yes	Yes
A330 LP compressor bearing collapse	Yes	Yes	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	No	Yes
A330 reverser unlocked	Yes	Yes	Yes	n/a	Yes	Yes	Crew	No	No	Yes	No	Yes	Yes	Yes

B.10 RESULTS.

Fokker 100	credit
Fokker 100 static port 2 blocked	0.64
Fokker 100 cooling fan motor inop.	0.68
Fokker 100 AHRS system 1 failure	0.89
Fokker 100 AC bus 2 short circuit/smoke	0.14
Fokker 100 DC bus 1 short circuit	0.57
Fokker 100 loss of both generators	0.50
Fokker 100 hydraulic system 1 leak	0.93
Fokker 100 GND/FLT sensor in GND	0.64
Fokker 100 anti-skid failure	0.79
Fokker 100 LP compr. bearing collapse	0.79
Fokker 100 fuel line leak	0.64
Fokker 100 reverser unlocked	0.61
AVERAGE Fokker 100	0.65

Fokker F-27 Mk500	credit
F-27 static port 2 blocked	0.36
F-27 LH vertical gyro failure	0.57
F-27 inverter 1 short circuit/electrical smoke	0.21
F-27 Main DC bus short circuit	0.29
F-27 pneumatic system leak	0.43
F-27 GND/FLT sensor in GND	0.36
F-27 engine oil leak	0.57
F-27 flight fine lock elec. circuit failure	0.46
AVERAGE F-27	0.41

Fokker 50	credit
Fokker 50 AHRS 1 failure	0.71
Fokker 50 DC bus 1 failure	0.71
Fokker 50 AC bus 1 short circuit	0.14
Fokker 50 hydraulic system leak	0.64
Fokker 50 GND/FLT sensor in GND	0.43
Fokker 50 engine 1 oil leak	0.79
Fokker 50 propeller electronic control fault	0.64
AVERAGE Fokker 50	0.58

Fokker F-28	credit
F-28 static port 2 blocked	0.36
F-28 vertical gyro 1 failure	0.43
F-28 AC bus 2 short circuit/electrical smoke	0.14
F-28 TRU no. 2 overheat failure	0.54
F-28 hydraulic system 1 leak	0.43
F-28 GND/FLT sensor in GND	0.36
F-28 LP compressor bearing collapse	0.29
F-28 fuel line leak	0.54
AVERAGE F-28	0.38

Boeing 737-500	credit
B-737 static port 2 blocked	0.36
B-737 IRS 1 failure	0.43
B-737 AC bus 2 short circuit/electr. smoke	0.21
B-737 DC generator drive 1 low oil pressure	0.61
B-737 hydraulic system A leak	0.50
B-737 GND/FLT sensor in GND	0.29
B-737 LP compressor bearing collapse	0.29
B-737 reverser unlocked	0.54
AVERAGE Boeing 737/500	0.40

Airbus A310	credit
A310 ADC 1 failure	0.79
A310 IRS 1 failure	0.86
A310 AC bus 2 short circuit/electr. smoke	0.54
A310 DC norm bus short circuit	0.79
A310 hydraulic system A leak	0.71
A310 LG pos detection failure	0.71
A310 LP compressor bearing collapse	0.71
A310 reverser unlocked	0.71
AVERAGE Airbus A310	0.73

Boeing 777	credit
B-777 air data system failure	0.71
B-777 ADIRU failure	0.79
B-777 AC bus 2 short circuit/electr. smoke	0.21
B-777 AC bus L failure	0.79
B-777 hydraulic system L leak	0.79
B-777 GND/FLT sensor in GND	0.43
B-777 LP compressor bearing collapse	0.79
B-777 fuel leak	0.43
AVERAGE Boeing 777	0.62

Airbus A330	credit
A330 ADR 2 failure	0.86
A330 IRS 1 failure	0.71
A330 AC bus 2 short circuit/electr. smoke	0.21
A330 DC bus 2 short circuit	0.71
A330 blue hydraulic system leak	0.86
A330 LGCIU 1+2 failure	0.71
A330 LP compressor bearing collapse	0.64
A330 reverser unlocked	0.71
AVERAGE Airbus A330	0.68

APPENDIX C—SIMULATOR RESULTS

C.1 SESSION 1.

Date: 24 February 2007
Start time 12:15, end time 15:45
Simulator operator: Fred Bergisch
Project pilot: Wim Huson
Experiment pilot: WWW
Observers: Alfred Roelen, Nico de Gelder

Simulated failures:

- DC bus 1 fault
- Loss of fluid from hydraulic system 1
- Blocked static tube
- Ground/flight logic switch failure after takeoff
- Engine seizure

Failure: DC bus 1 failure.
Initial conditions: FL 300, mass 38 tonnes, c.g. 25%, VMC daylight. Project pilot is PF.
Observations: The final status page on the RH MFDU provides good feedback, the experiment pilot knows the procedure has been completed.

Failure: Hydraulic system 1 leak.
Initial conditions: FL 100, River holding, mass 38 tonnes, c.g. 25%, VMC daylight. Project pilot is PF.
Observations: A level 2 L MAIN LG DOOR and R MAIN LG DOOR appears while executing the ALTERNATE LANDING GEAR procedure. Even though this was announced in the procedure description, it caused a hesitation in the completion of the procedure. As a general comment, it was noted that the transition form the MFDU to the QRH is not clear. There is no indication at all on the MFDU that (additional) procedures from the QRH need to be completed.

Failure: Blocked static tube, RH side.
Initial conditions: EHAM runway 24, flaps 15, engines running, mass 38 tonnes, c.g. 25%, VMC daylight. Experiment pilot is PF.
Observations: The failure is detected after the COMPARE SPEED alert. The fact that the altimeter indicates remains at 0 ft is not noticed. After correctly selecting the alternate source and further completion of the procedure, there remain some Flight Mode Annunciations (FMAs) on the EFIS display that are disregarded because the experiment pilot does not understand what they mean. During the approach to land, as the airspeed drops below 200 kts, the experiment pilot omits to select the LO speed mode of the manual rudder limiter. During the debrief, the experiment pilot explains that although he correctly completed the procedure he did not understand the cause of the alert.

Failure: Ground/flight logic switch failure after takeoff.

Initial conditions: EHAM runway 24, flaps 15, engines running, mass 38 tonnes, c.g. 25%, VMC daylight. Project pilot is PF.
Observations: The additional information in the AOM is not consulted, the experiment pilot is therefore unaware of the fact that the following systems may be affected cabin pressurization, stall protection, lift dumper auto disarming after takeoff, wing and/or tail anti ice, MFDS (no flight phase inhibition, no procedures display), FMS (no aircraft position prediction), EFIS (VSS and VMA not displayed), ATC transponders.

Failure: Engine seizure.
Initial conditions: FL 300, mass 38 tonnes, c.g. 25%, VMC daylight. Project pilot is PF.
Observations: The experiment pilot noticed the TGT overtemp because the indication changed from green via amber to red. On trying to complete the ‘airco auto shut off..........as required’ procedure the experiment pilot cannot locate the associated pushbutton on the overhead panel. Note: This pushbutton is located on the pressurization control panel and not on the air conditioning panel. The experiment pilot therefore decides to ignore this part of the procedure.

C.2 SESSION 2.

Date: 13 March 2007
Start time 16:15, end time 19:45
Simulator operator: Fred Bergisch
Project pilot: Gerard Temme
Experiment pilot: XXX
Observers: Alfred Roelen, Rombout Wever

Simulated failures:

- Thrust reverser unlocked
- Anti-skid fault (annunciated)
- Electrical smoke
- Blocked static tube
- Engine seizure
- IRS sensor drift

Failure: Thrust reverser #2 unlocked.
Initial conditions: FL 100, River holding, mass 38 tonnes, c.g. 25%, VMC daylight. Experiment pilot is PF.
Observations: The experiment pilot initially thought this was a level 3 warning due to the color of the procedure annunciation on the MFDU (the amber was rather dark and not easy to distinguish from the red). Apparently this cue was more compelling than the double chime and amber master caution light that indicate a level 2 alert. Experiment pilot therefore started with the 'red' section in the QRH to find reverser unlocked procedure. When he could not find the procedure, he looked it up in the index.
The reverser unlocked procedure includes: LIFTD (OVHD panel).........OFF. It took quite some time before the LIFTD pushbutton was located on the overhead panel. It is not automatically illuminated and the experiment pilot was initially confused because he was expecting actions related to the engine, while LIFTD is in the hydraulics section of the overhead panel. The caption LIFTD was not self explanatory, the experiment pilot did not know what it indicated. On the pedestal the lift dumper arm pushbutton has "LD arm" caption, hence inconsistent with the LIFTD caption on the overhead panel …
The reverser unlocked procedure does not require shutting off the engine. The experiment pilot thought this was illogical and decided that it was better to shut down the engine. The engine shutdown procedure was completed. The APU was started. There was no immediate feedback to indicate that the APU indeed had begun operating. Feedback is provided approx. 10 sec after APU start when EGT rises. The aircraft was landed under the single engine procedure and accordingly 25 degrees of flaps were selected. The fact that the initial reverser unlocked procedure calls for a zero flaps landing had not been remembered.

Failure: Anti-skid fault (annunciated).
Initial condition: Approach to EHAM RWY 06, landing gear down, mass 38 tonnes, c.g. 25%, VMC daylight, engine # 2 inoperative, reverser # 2 deployed.
Observations: Procedure completed according to the book, no difficulties encountered. The Experiment pilot remembered to be careful applying brakes in landing roll.

Failure: Electrical smoke.
Initial condition: FL 300, mass 38 tonnes, c.g. 25%, VMC daylight. Project pilot is PF.
Observations: The full procedure was executed, i.e., including donning the oxygen masks. The smoke removal procedure was not executed because the smoke had already disappeared. Feedback when executing manual rudder limiter procedure in pushbutton of rud lim (hi/lo mode) is good.

The electrical smoke procedure requires selection of essential and emergency power only. This has a significant effect, the right-hand main instruments disappear and there is a long list of consequential failures. The experiment pilot was surprised by this big step.
The long list of consequential failures was deliberately ignored by the experiment pilot. Consultation of the AOM after completion of the procedure confirmed to him this was indeed the correct choice.

Failure: Blocked static tube.
Initial condition: EHAM runway 24, flaps 15, engines running, mass 38 tonnes, c.g. 25%, VMC daylight. Experiment pilot is PF.
Observations: The experiment pilot noticed almost immediately after takeoff that the speed indication was reducing. Initially, he lowered nose to 10 deg of pitch, and when speed further reduced, he crosschecked the speed at the PNF instruments. Pitch attitude confirmed to him that there was a problem with the speed indication. The experiment pilot concluded his own speed indication was erroneous and control was handed over. He also noticed that the altitude indication remained zero. He suspected an air data computer failure. A whole list of alerts was presented; in fact, there were so many that the pilot did not know where to start. Experiment pilot started with the procedure displayed first on the MFDS and selected alternate source. Amongst others a 'STALL COMPUTER FAULT' appeared. The experiment pilot initially had difficulty in finding the associated procedure in the QRH (it appears under the heading of 'flight controls').
Check video to confirm that no compare speed was annunciated.

Failure: Engine seizure.
Initial condition: FL 300, mass 38 tonnes, c.g. 25%, VMC daylight. Project pilot is PF.
Observations: Initial annunciation is TGT overlimit. Engine flameout is observed by the experiment pilot. Since fuel lever light is white, and not red, experiment pilot thinks there is no engine fire. Based on engine indications, the experiment pilot starts QRH eng fail procedure. Later when Eng fail procedure appears on MFDU, the experiment pilot is surprised and recognizes he should have checked checklist on MFDS first.

Single engine failure procedure is followed. At the 'if damage...' step in the procedure the experiment pilot did not know whether there was damage or not. The project pilot assisted by stating he suspected damage and the engine severe damage procedure was completed. Slight hesitation from the experiment pilot to discharge the extinguisher; again, the project pilot assisted. In the debrief, the experiment pilot explained that he had not observed the N1 and N2 indications (N1 read zero), and therefore thought it was a normal flameout rather than a severe engine damage.

Failure: Right-hand IRS sensor drift.
Initial condition: EHAM runway 24, flaps 15, engines running, mass 38 tonnes, c.g. 25%, VMC. Experiment pilot is PF.
Observation: The failure is noticed after a 'compare attitude' alert. The experiment pilot immediately suspected his attitude indication to be faulty and switched to alternate source without consulting the associated procedure and without comparing the primary indications with the standby horizon. Since the airspeed and altitude indications on the PFD are correct, the experiment pilot decides to keep the PFD with erroneous attitude and not switch it off.

Overall comment from the experiment pilot: The transition from following the procedures on the MFDU to consulting the QRH is difficult. It is not immediately clear where to find the relevant procedure in the QRH.

C.3 SESSION 3.

Date: 3 April 2007
Start time 16:15, end time 19:45
Simulator operator: Fred Bergisch
Project pilot: Gerard Temme
Experiment pilot: YYY
Observers: Alfred Roelen, Rombout Wever

Simulated failures:

- IRS sensor draft
- Engine flameout
- Reverser unlocked
- Loss of AC power
- DC bus 1 fault

Failure: Right-hand IRS sensor drift.
Initial condition: FL 100, River holding, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: Failure was noticed only after the COMPARE ATTITUDE alert. Procedure from the MFDS is followed. Comparison of the primary and standby attitude indicators convinces the experiment pilot that his indication is incorrect, alternate source is selected.

Failure: Engine number 2 flameout.
Initial condition: FL 300, mass 38 tonnes, c.g. 25%, VMC daylight. Experiment pilot is PF.
Observations: Engine flameout procedure is correctly executed. Some trouble in locating the single engine procedure because the experiment pilot expects to find it in the emergency procedures section, while actually, it is part of the abnormal procedures. When the APU START switch is selected to START there is no immediate feedback, the experiment pilot thinks nothing is happening, switches back to OFF and then to START again. Only then EGT starts to rise as indication of a starting APU, and seconds later the indicator light also illuminates (note: recycling the APU switch was not necessary, the APU just needs some time to start). On trying to complete the 'airco auto shut off..........as required' procedure the experiment pilot cannot locate the associated pushbutton on the overhead panel. Note: this pushbutton is located on the pressurization control panel and not on the air conditioning panel. The 'as required' part is also considered ambiguous because the pilot does not know the associated criteria. On selecting Maximum Continuous Thrust (MCT) on the thrust rating panel the experiment pilot initially does not observe any change. Only when MCT is deselected and then selected again does he see a small change in the engine parameters on the left MFDU. Because it is a 'normal' flameout the experiment pilot decides to try a relight. There is some confusion on the START pushbutton that is part of the relight procedures. The experiment pilot only sees an 'ENGINE START' pushbutton and hesitates if this is the same as the 'START' pushbutton that is mentioned in the procedure. When the experiment pilot checks the AOM after completion of the QRH procedures he discovers that he should have disconnected the ATS before retarding the thrust lever, and that it should be re-engaged after completion of the procedure. During the debrief the experiment

pilot commented that the white light in the fuel shut off switch proved a good indication of the affected engine.

Failure: Reverser unlocked.
Initial condition: FL 100, River holding, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: The experiment pilot initially has difficulty in locating the LIFTD pushbutton on the overhead panel. While executing the procedure, there is a fuel asymmetry alert. The crossfeeds are opened and the experiment pilot continues the reverser unlocked procedure. Initially, he returns to the wrong line of the reverser unlocked procedure (omitting the 'liftd....normal' step), but this is quickly corrected. The procedure is executed twice because there is no apparent result. The experiment pilot has great difficulty in locating the 'landing with flaps less than 25' procedure. (It is in the 'flight techniques, abnormal operation' section of the AOM). The experiment pilot has some difficulty in locating the GPWS FLAP OVRD switch (it is located on the overhead panel).

Failure: Loss of both electrical power generators. Generator 1 fails first, seconds later followed by generator 2.
Initial condition: Aircraft is dispatched with an inoperative APU. FL 100, River holding, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: Immediately after the GEN 1 failure the experiment pilot executes the correct procedure (GEN...OFF THEN ON) but coincidentally GEN 2 fails at precisely the moment of depressing the GEN 1 pushbutton (this was purely coincidental and not prearranged for the experiment). This generates a whole list of failures, including an AC BUS 1 and an AC BUS 2 failure message. The experiment pilot quickly understands that he has a serious electrical problem. The problem is finding the correct procedure. Because the AC BUS faults are level 2 messages, the experiment pilot tries to locate the procedure in the abnormal procedures section of the QRH, but this only contains procedures for a single AC bus failure and not a dual AC failure. At the suggestion of the project pilot, he then refers to the emergency procedures section and correctly identifies and executes the 'LOSS OF BOTH ENGINE GENERATORS' procedure.

Note: The standby annunciator panel came on automatically after loss of both generators. A red AC SUPPLY alert light was illuminated. This information was not consistent with the information on the left-hand MFDU: the wording was different and indication was red rather then the amber on the MFDU. However, the information on the standby annunciator panel was not used by the experiment pilot.

Failure: DC bus 1 fault.
Initial condition: FL 100, River holding, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: The experiment pilot has some difficulty in locating the manual rudder limiter pushbutton on the overhead panel.

C.4 SESSION 4.

Date: 10 April 2007
Start time 16:15, end time 19:45
Simulator operator: Fred Bergisch
Project pilot: Peter Broos
Experiment pilot: ZZZ
Observers: Nico de Gelder, Rombout Wever

Simulated failures:

- Avionics cooling failure
- Landing gear selector blocked in the down position
- Engine flameout
- Electrical smoke, short circuit AC bus 2
- Hydraulic system 1 low quantity
- Landing gear selector blocked in the down position

Failure: Avionics cooling failure.
Initial condition: FL 100, River holding, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: Failure is recognized by experiment pilot, and procedure in QRH is executed. Standby engine indications have to be switched on, as well as standby annunciator panel. Experiment pilot completes procedure. The flight crew decides to return to the airport and meanwhile they receive a red warning on the standby annunciator panel indicating ‘LG’ (not part of the experiment). The experiment pilot looks for this failure in the QRH and is unable to find a corresponding emergency or abnormal procedure. This is confusing to both pilots. At that moment, the aircraft levels off and power is increased by autothrottle system, and the warning disappears. Now the pilots recognize the cause of this alert: it was a warning that the gear was not down with the thrust levers retarded.

In the QRH, it is mentioned that one can expect failure of the RH EFIS and both MFDS DUs after approximately 15 minutes. The experiment pilot found this guidance unclear, in the sense that he did not know whether or not these units would be available after 15 minutes. He could switch them off too cool them and later switch them on in the approach and landing. This is mentioned in the AOM, and would have been useful information to include in the QRH.

Failure: Landing gear selector blocked in the down position.
Initial condition: EHAM takeoff runway 24, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PNF.
Observations: Experiment pilot tries several times to raise gear. Since unsuccessful they climb to holding (FL 100) while monitoring speed. Experiment pilot asks PF to try to raise the gear and when he is also unsuccessful, experiment pilot starts QRH checklist. LG override does not solve the problem, and flight crew returns to airport with gear down. Experiment pilot checks the cabin pressurization to get confirmation that the problem is not related to a fault in the ground/flight logic switch.

Note: Due to simulator setup it was not possible to select the ground/flight logic failure as was intended.

Failure: Engine 2 flame-out (restart possible).
Initial condition: FL 200, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PNF.
Observations: The yawing motion, noise, and vibration were first indications for the experiment pilot that the engine had failed, followed by the engine failure warning. Diagnosis of flameout based on N1 and N2 readings. The engine failure procedure was correctly carried out by experiment pilot. When APU was started, the experiment pilot did not receive immediate feedback that he had actually started, the APU, which he found confusing. He asked whether the APU had started (something happening?), but when he saw after a few seconds the APU temperature rising it was clear to him that the APU had started. The EGT starts to rise as indication of a starting APU, and seconds later the indicator light also illuminates ‘AVAIL’. The crew received a fuel asymmetry caution (level 2) for which they carried out the procedure (cross feed selected).

Failure: Electrical smoke (AC bus 2 short circuit).
Initial condition: FL 100, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: When smoke enters cockpit crew takes action, first donning the smoke masks. The experiment pilot carries out the electrical smoke procedure. After selecting ESS+EMER power a number of warning messages appear on the MFDU, but the experiment pilot ignores these for the moment since he believes these are related to selecting emergency power. Experiment pilot skips the bus equipment list since they are close to the airport and it is too much workload with low priority at that moment. As the smoke clears, they remove their masks. The experiment pilot has no trouble finding the rudder limiter pushbutton on the overhead panel. There are two pushbuttons, one above the other. The upper pushbutton is for selecting the rudder limiter to manual, the second, lower pushbutton is for selecting the rudder limiter to high or low speed mode. The project pilot thought the one was for high and the other for low speed mode, since the labeling next to these two pushbuttons is ambiguous. Next to the lower pushbutton the letters ‘SPD’ is printed, and next the upper pushbutton no label is printed.

Experiment pilot notices there is no procedure for smoke of unknown origin.

Failure: Hydraulic system 1 low quantity.
Initial condition: FL 100, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PF.
Observations: Experiment pilot carries out abnormal procedure successfully from the MFDU. The first item reads: “SYS 1 ENG 1 AND 2 PUMP ... CHECK OFF’. The experiment pilot selects eng pump 1 of system 1 off, then continues checklist. The project pilot then advises the experiment pilot to check what the procedure states. The experiment pilot discovers that he has misread the first action item and suggests that in a case where two pumps have to be switched off, it would be better to have two separate action items in the procedure in stead of combining these two in a single sentence. His suggestion would be:

```
SYS 1 ENG 1 PUMP ...  CHECK OFF.
SYS 1 ENG 2 PUMP ...  CHECK OFF.
```

In the QRH, there are two references in the hydraulic system 1 failure procedure, one referring the QRH section in which the alternate flap procedure can be found, and the other reference is to the QRH section with the alternate gear procedure. These references are printed below the hydraulic system 1 failure procedure in the QRH and are linked with a black line from the action item line in the hydraulic system 1 failure procedure to the corresponding reference. However, the first QRH reference is linked with the second line in the hydraulic system 1 failure procedure, and the second QRH reference is linked with the first line in the hydraulic system 1 failure procedure; i.e., alternate flap procedure is first action item in the hydraulic system 1 failure but is the second reference. Although both the action item and the reference are linked by a line, this is ambiguous, and the experiment pilot is momentarily confused as he cannot find the correct procedure in the QRH section.

Failure: Landing gear selector blocked in the down position.
Initial condition: EHAM takeoff runway 24, mass 38 tonnes, c.g. 25%, IMC daylight. Experiment pilot is PNF.
Observations: Anti-skid fault and lift fault messages appear on the left MFDU. The experiment pilot tries to raise gear but does not succeed. The crew levels off at FL 100 while monitoring speed. Experiment pilot starts abnormal procedure for landing gear selector blocked in down position, and the anti-skid fault. Procedure does not solve the problem. Flight crew checks the required landing distance with these faults and lands at Rotterdam airport.

Note: Due to simulator setup, it was not possible to select the ground/flight logic failure as was intended.

APPENDIX D—MATRIX SESSION

D.1 OBJECTIVE.

The objective of the 'matrix' sessions is to obtain insight into the argumentation used to take decisions on the design of the Fokker 100 cockpit with respect to failure handling. This empirical approach is then compared with the systematic method developed in this project as a 'validation' of the latter.

D.2 APPROACH.

The actual matrix sessions took place during the development of the Fokker 100 in the early 1980s. Participants were the chief experiment pilot, project experiment pilots, cockpit design engineers and various system engineers. The objective of those meetings was to reach consensus on cockpit design with emphasis on the warning logic. We tried to recreate those discussions by inviting three key persons in the development of the Fokker 100 cockpit: Jaap Hofstra (experiment pilot), Wim Huson (experiment pilot), and Henk de Groot (cockpit design engineer). The role of system engineers was played by NLR engineers. Fokker F-28 handbooks were available for reference, because many of the F100 systems were based on the F-28.

Start of the discussion would be a particular failure of a system in a certainflight phase. Typical questions to feed the discussion were the following:

- What should be annunciated?
- How should the annunciation be done?
- What is a suitable annunciation level?
- What is presented centrally? What is presented locally?
- Is audio necessary?
- Is a dedicated annunciation necessary?
- Should there be any inhibition? What is inhibited by the failure? What inhibits the failure?
- What should be presented on the multifunction display unit?
- What should be presented in the QRH?
- What should be the status of the aircraft?
- What additional information should be presented in the AOM?
- Which actions are expected from the flight crew?

Some general considerations:

The Fokker 100 is a short range aircraft, so it will always be in relative proximity to an airfield. In case of a failure, the immediate consequences should be mitigated, and the aircraft should land. The flight crew is not expected to start troubleshooting.

D.3 RESULTS.

The sections below represent an almost verbatim account of the discussion.

Blocked static tube during takeoff, right-hand side.
Assume RH pilot is PF. During the ground part of the takeoff this will not be noticed by the flight crew. How does one notice this? Is there some way to inform the flight crew? The failure will have effect on the indication of airspeed and altitude. This can only be noticed during the climb. The altitude will remain zero, the vertical speed will remain zero and the speed indication will decrease.

First, the effects on the aircraft must be clear. Standby instruments and the left main instruments retain correct indication. It will not be noticed during the takeoff roll. This is not a problem because it is not an issue. During climb the altitude indication will be lagging and the airspeed indication will drop. Only the right-hand side is affected, left-hand side will have proper indications. What is most critical, PF or PNF? PF will notice immediately that the altitude indication remains zero because the altimeter is in his primary scan. He will be confused. Reading the standby altimeter from the right-hand seat is not very easy due to its location. The call for gear up will be given after 'positive climb', but is the vertical speed indicator used? Due to the disturbed airflow at rotation, the vertical speed indication is not reliable. Vertical speed is assessed initially from the radio altimeter or a rough estimate. The gear-up action is so automatic that it will not be forgotten. The PF will hand over control. A failed altimeter can cause some stress. The altimeter is a primary instrument. A failed indication will be noticed before the aircraft reaches 400 ft. But it also influences airspeed indication. Speed indication could drop below stall speed. When the pilot is not aware of the context, he will push the nose down. Airspeed will increase. Initially the reference is pitch and not airspeed. How big is the error? At 200 ft, there is already a 10 kts speed error. So during rotation, the aircraft seems to decelerate. A pilot does not have system knowledge. He flies procedures. In the takeoff, the pilot is in a stove pipe. He will not notice a speed deviation. The sound is normal, the acceleration will feel normal. After gear-up, it will gradually become apparent that something is not right. He must come out of the stovepipe and start thinking. The first thing is that something is wrong with the instruments and control will be handed over. But if the speed reduces it will be difficult not to decrease pitch. Apparently, the situation becomes more hazardous. The PNF will remark that the PF is not following the flight director. If the PF tends to decrease pitch, the flight director will indicate to increase pitch. The GPWS will call out 'don't sink'. If there are no further complications, this will provide sufficient means for detection.

Is it possible to develop an altitude comparator? No, this is not possible because the PF and PNF will make the transition to/from Queens Nautical Height (QNH) at a different moment. Are there other systems connected to the static port that would allow a comparison? The F-28 does not have an air data computer. In the Fokker 100, it is less complicated to compute the difference. What would be the added value of a compare speed warning? For the altitude, there is always an alternative in the radio altimeter. For airspeed, there is no such alternative. A compare speed warning provides situational awareness. Comparison of left and right static pressure will create nuisance warnings in crosswind situations. The autopilot is also connected to the pitot-static system, so the whole system will be affected. At least half of it. It is for the pilot nice to know why something is not correct. All kinds of strange things are happening and the pilot does not have sufficient system knowledge to diagnose correctly. The air data computer cannot know that the static pressure is incorrect.

What should be the alerting level of a compare speed warning? Is it just as serious as an engine fire? No, the aircraft continues flying. The failure will be detected regardless of any annunciation because the PNF will notice that the PF is doing something strange. What is the added value then of a dedicated annunciation? A compare speed tells that there is something wrong, but it does not specify. The fact that something is wrong will already be noticed by the PNF. Is there a possibility that additional failures are created by a compare speed warning? Is there a possibility of nuisance warnings? This should never be used as an argument. If there are such problems they should be solved. There seems to be no business case for a compare speed warning. It only introduces additional stress.

Hydraulic system 1 leak in tank.
How does one find out? What will happen? A quantity indicator is located on the overhead panel, but the pilots will never look at this. It will be noticed when flaps are selected. But this is too late. You want to know much earlier, you want to know as soon as the leak has developed. Then you can take appropriate measures such a diverting to another field that has longer runways. A dedicated annunciation is necessary. Can a Cat III landing be performed with this failure? This must be known as soon as possible. So the flight crew must be aware before use of hydraulic system is actually necessary. Flight crew does not look at the overhead panel, so there cannot be just a local light. The local light must be annunciated. The overall status of the aircraft must be presented; the pilot must be aware of the consequences of the leak. What should be the level of the annunciation? Is immediate action required? No, so not a level 3. Is immediate awareness of the failure required? Or is a level 1 sufficient? A consequence of a level 1 would be that it is not shown below 1000 ft (according to the current philosophy). This is also not what you want because you then deprive the flight crew of an opportunity to divert to another field even though there is plenty of time.

As long as there is hydraulic pressure, a leak in the system has no consequences. What will be annunciated first? Loss of hydraulic pressure is a level 2 warning. We do not want the pilot to start troubleshooting. So a level 1 is appropriate, standard inhibition. So do not show at below 1000 ft. What procedure? Check quantity. Without hydraulic pressure the aircraft can still be flown. It is unpleasant if the failure occurs just before landing. There is a marked difference between the flight phases. But on the other hand, the probability of the failure is much lower during the final part of the approach (because of the short time). Every failure will have the same warning level throughout the flight phases. The warning level cannot be made a function of the flight phase. Still, no reason to make this (the leak itself) a level 2 warning. What would be the best thing to do when a low pressure occurs during the approach? Continue the landing or go-around?

Retrospective note: Actually, the hydraulic low quantity is a level 2 in the Fokker 100. The reason is that the hydraulic pumps should be switched off so as to conserve hydraulic fluid as much as possible. Pumps are switched on again when the aircraft is configured for landing.

Engine failure, low pressure bearing collapse.
N1 reduces. Disturbed airflow will enter the engine. Is this audible? An engine failure will result in many consequential failures. Can a failed engine be detected by the system? Then the flight crew will not only react on the consequential failures. But you do not want to annunciate that a bearing has failed. You want to annunciate that the engine has really failed, that this is really true, and that the engine cannot be restarted. The flight crew must be instructed to close the fuel. An engine seizure can occur in so many different ways that it cannot be annunciated as such. We do not have the technology to annunciate this unambiguously. Sound, bangs, vibrations. There is a level 1 or level 2 annunciation for vibration. This only tells you that the engine vibrates. After an engine seizure, all engine indications will be abnormal. We no not have the technology to combine this information. An engine failure can be annunciated, but it is impossible to make a distinction between failure where a restart is possible and those where a restart is not possible. Explicit annunciation is not necessary, because it is obvious that something is wrong. 'Apply single engine failure procedures' is not presented on the display but has to be on paper because there are different versions for different airlines.

Leak in the hp fuel line, downstream of the shut-off valve.
The booster pumps will continue working, low pressure pumps will also continue working, the flow will remain. It depends on the size of the leak whether the engine will flameout or not. A small leak is dangerous. The only indication is a small increase in the fuel flow, but this will not be detected because there is always a bit of a difference in the fuel flow of the L and R engine. If the leak is somewhat bigger, a fuel asymmetry will develop. There is also the possibility of a fire, and this could result in an engine fire indication. The fuel asymmetry alert is presented rather late. If there is a flameout, the booster pumps will continue working so the fuel will continue to flow. A fuel leak will remain unnoticed, a larger leak will result (eventually) in fuel asymmetry. Suppose you know that there is a fuel leak. Don't you want to shut down the engine? No, shutting down the engine would result in loss of many systems. Maybe you want to reduce to idle thrust. The engine will flameout if the leak is very big. In all three cases, there is a possibility of a fire. A small leak is not a problem, as long as it does not result in a fire. It will be detected after the flight, during maintenance. Because it is a short range aircraft it is not possible to determine if the fuel consumption is higher than planned. There are always differences in fuel consumption between the left and the right engine. If the leak is large, it will result in fuel asymmetry. An annunciation is generated when the asymmetry exceeds 250 kg. This is a direct result of regulation. The caution level depends on the controllability of the aircraft. It should be a level 2, direct awareness. It can be inhibited below 400 ft. If it occurs lower, you should simply land. The caution level depends on the controllability of the aircraft. The leak will continue, even if the warning is inhibited. From 400 ft, there remain only 30 seconds to touchdown. The warning could even be inhibited at 1000 ft. It will then be a special

case, a level 2 with inhibition at 1000 ft. It is only really relevant in cruise; at 400 ft, you don't want to be bothered with this.

Electrical smoke.

Behind the co-pilot sits the main electrical board. High power runs from the back of the aircraft all the way to this main electrical board. And one of the main consumers is the galley, which sits all the way in the back! If electrical smoke occurs, we can assume it comes from this main electrical board. Can electrical smoke emerge from the air conditioning openings? Is it possible to distinguish between the two types of smoke, electrical and airco? The difference can be smelled. Obviously, the smoke will enter the recirculation and then will also come out of the air system. Is it important for the pilot to know what type of smoke it is? Yes, it is potentially life threatening, it is one of the worst things that can happen to you. Priority one is fresh air, oxygen, and the ability to see. First action is donning the oxygen mask, second priority is vision, then composure, and finding the cause. Smoke removal is done only after the source of the smoke has been killed. But how can you do something when it is impossible to see because of the dense smoke? It can all happen very quickly. You should begin with removing all electrical power. But you don't want to turn off the generators. How can the pilot be assisted in detection? How does the pilot know where to start? You cannot help. It is an unannunciated failure. The F-28 does have a detection system for cargo smoke. Why has this not been installed in the cockpit? Because smoking was still allowed when the cockpit was developed. It is up to the pilot to determine whether there is electrical smoke or air conditioning smoke. What often happens is that the cause of the electrical smoke sets the insulation blankets on fire. Removing the power will not stop this fire from burning. What should be the procedure? First, switch to emergency power. Only a little bit more than battery power should remain. You want to keep as many systems as possible alive with the least possible smoke. The airlines always want to keep everything alive, they want to have as many systems as possible on the essential bus. Details are important. It is useless to have the displays powered up if the sensors that feed the displays remain powerless. It is required to be able to keep flying for 30 mins on battery power only. Is a RAT needed? This has been discussed but has been dropped because of the complications. What are the criteria for the procedure 'Land ASAP'? There are situations in which it cannot be guaranteed that the aircraft is as safe with the failure as without the failure. It is then only possible to prescribe to land as soon as possible. You do not want to tempt the pilot to continue to the destination; e.g., on a flight from Amsterdam to Munich, if the failure occurs while the aircraft is above Frankfurt, you want them to land in Frankfurt and not continue to Munich. It is also necessary to land as soon as possible because of the limited capability of the battery.

Smoke removal.

Smoke can only be removed via the outflow valves. Recirculation is switched off. Fly to a lower altitude where the air is thicker. Do not open the cockpit window because the underpressure will suck the smoke forward. Communication (in the cockpit and with ATC) is difficult with an open cockpit window. The smoke removal procedure is not something that requires exceptional skills.

IRS failure. (difference in attitude indication, assuming a version of the aircraft that is equipped with 2 IRS systems)

Gradually increasing difference between left and right attitude. Keyword is threshold. Is a difference alert desired? Attitude is vital for the pilot, it is perhaps even the most important parameter. But there are two systems, separated. The other pilot will see that something unusual is going on. But the other pilot is sometimes busy, or needs to go to the toilet. How is the autopilot affected? The autopilot is coupled to one side. If there is a difference, the system will not know which one is faulty. If the pilot is flying manually, there is always heading and the slip indicator. Limited panel. But it is questionable if current pilots still have those skills. The nasty thing about it is that it is difficult to ignore instruments even if you suspect that they are faulty. It can lead to vertigo. So there needs to be an annunciation. The standby will tell which of the two indications is correct. What kind of annunciation is necessary? If there are two systems it is impossible for the system to tell which one is at fault. The standby is a stand alone system. It does not have an electronic output signal. The standby instruments are on the left panel. Without annunciation, a normal pilot will not detect that the indication on the main instrument deviates from the standby indication. The danger is that both pilots are very busy, high workload environment, in a turn and then this failure occurs. That's what is so dangerous about it. So a comparator warning that goes off when the difference is substantial, 5 degrees or so. You cannot expect that pilots will analyze, so we need to know what we want the flight crew to do. Compare with the standby indication, decide which system is at fault, and then switch to the correct system. You are then single source so it has consequences for autoland capabilities. It should be a level 2, immediate awareness with subsequent action. No inhibition, attitude is of utmost importance. So the procedure is to compare the standby with the main indications and determine which one has to switch to the alternate source. Will a pilot be able so detect a difference of 5 degrees? Yes, certainly. Even a 1-degree difference is quite easy to detect, but the threshold cannot be too low because of nuisance alerts. Actually, you should first fly level before you do the comparison, because the standby instrument can deviate in a turn. The compare attitude is not displayed on the PFD. It is annunciated with a central warning.